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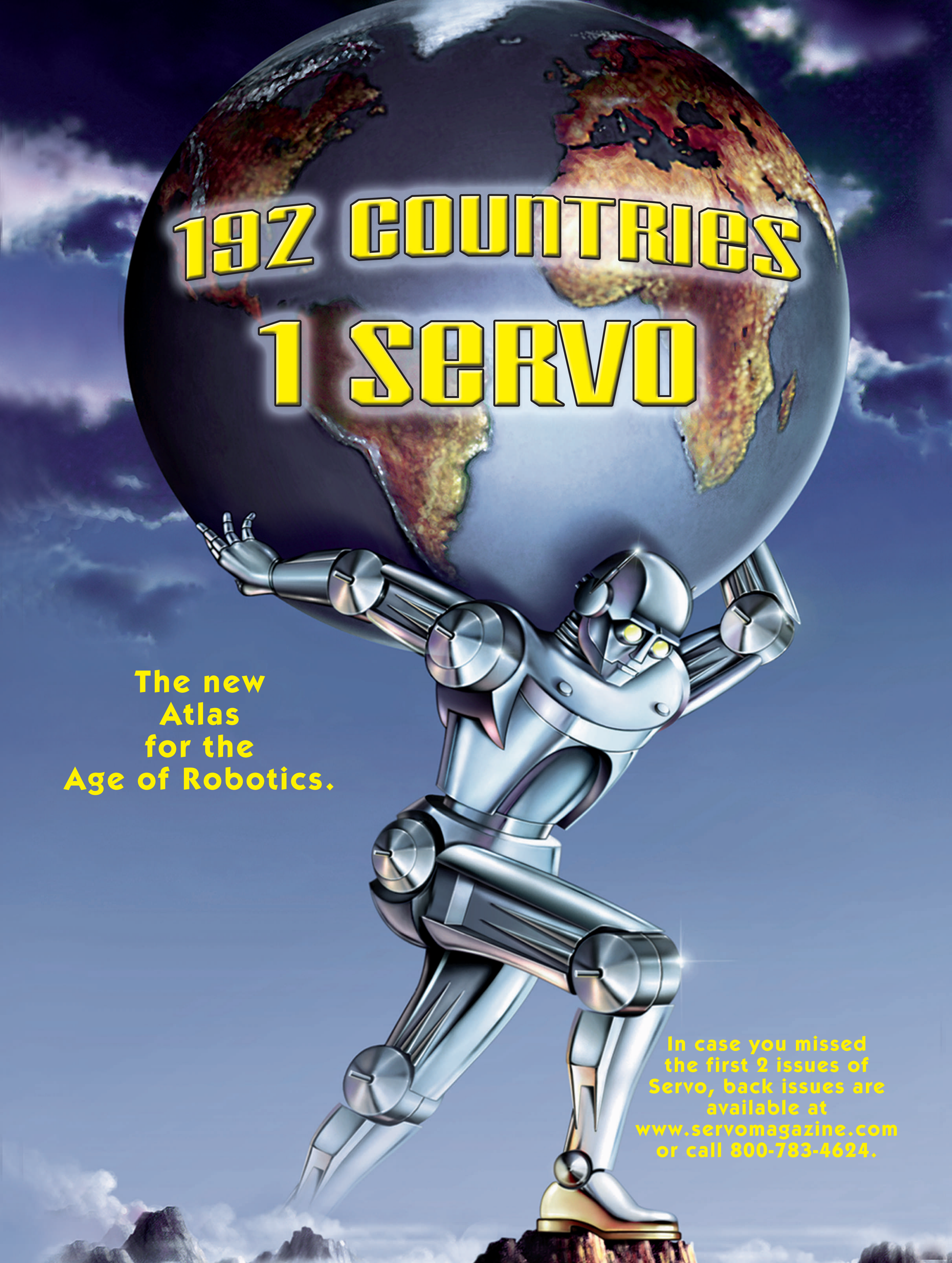

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Dear Nuts & Volts:

You guys are doing a really great job with your magazine and seem to be hitting technology at the right level where it is both fun and rewarding. As a suggestion, however, a few of your analog circuits may need a little "tune up" before they will work properly and deliver what they promise. For example, the phono preamp circuit first published on page 28 of the August, 2003 issue (and later republished on page 26 of the November, 2003 issue) needs a little help. I have a few tidbits of information that may be beneficial to the many readers who are interested in this topic, if you care to pass them on.

Don Stulken
Marion, IA

*We *are* interested in passing along Don's 24 pages of circuits and notes! If you would like a copy, send us a 9" x 12" SASE (with two 37 cent stamps) and we'll get you a copy.*
— Editor Dan

Dear Nuts & Volts:

I work overseas as an electronics technician and get the *Nuts & Volts* magazine sent to me and I really enjoy it. I was reading the article "Add A Touch of Control" in the November 2003 issue and would like to bring something to your attention. Many years ago when I lived in the US, I was a volunteer with the local United Cerebral Palsy (UCP) center. I constructed special switches that the physical, occupational, and speech therapists used with the children. A touch switch was the one used by the occupational therapists the most. A toy was modified so the touch switch controlled it.

This was done to show the small children they could use a switch to control something before they were introduced to their electric wheelchair. If any of your readers are looking for ways to use their talents in electronics, I highly recommend that they check with the local UCP center in their area.

Jim McLaughlin
via Internet

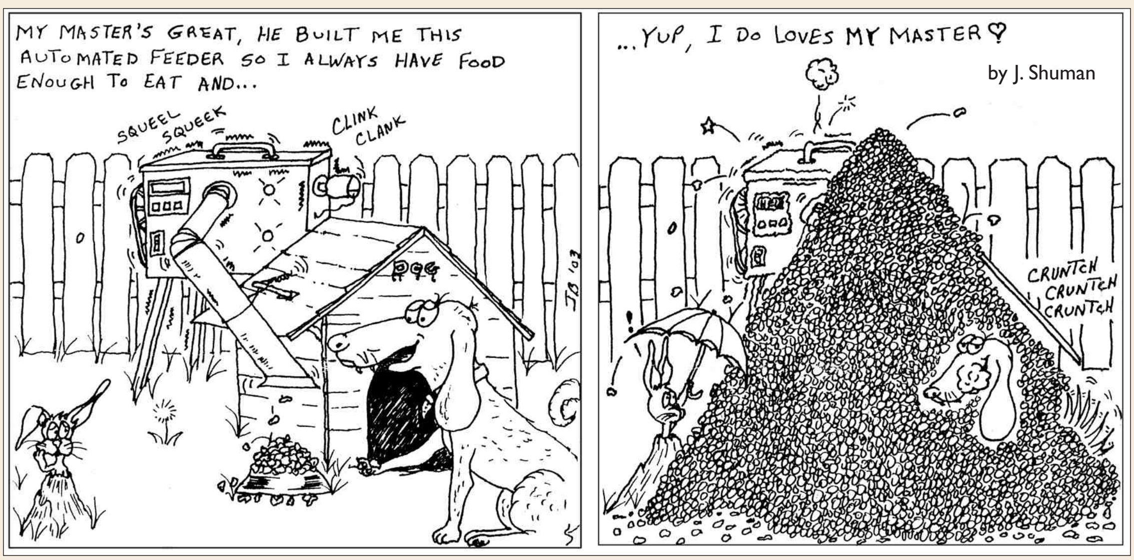
Dear Nuts & Volts:

In reference to "In the Trenches," December 2003 ... A lot of good information in this month's column. You made a reference to cutting plastic sheet material on a table saw. If you use the correct blade, it works very well. Regular wood cutting blades chip the plastic and make a poor cut. I was able to obtain a 10" circular saw blade made just for cutting plastic. The saw is made by Freud, model LU94, and can be obtained at McFeely's (**www.McFeelys.com**). The current price is around $70.00. I use the same blade to cut printed circuit board stock.

As always, when using a tablesaw, use the appropriate push sticks and other safety guards that came with the tablesaw. The blade does collect bits of melted plastic around the teeth, so you need to clean it on a regular basis.

Mike Suhar WB8GXB
Dayton, Ohio

Last month's "In The Trenches" column was unexpectedly truncated on page 85. The complete, ending sentence of Gerard Fonte's work was "Hopefully, you've found a tip or two that can help you work through some difficult spots." — Editor Dan



Devoted readers may notice that Stanley York's "Laser Insight" column is absent this month. Stanley's employment has taken him out of the country recently, and that, coupled with the natural end of his series, brings us to a turning point for this column. We hope to alternate features on laser technology with the emerging interest in near-space experiments in the coming year, inviting *Nuts & Volts* readers to join in the growing adolescence of this new field of endeavor.

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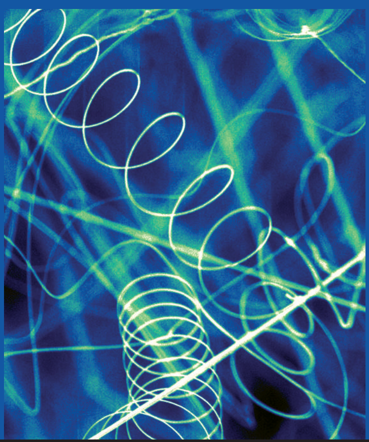
Events, Advances, and News From the Electronics World

Advanced Technologies

Nanosprings Offer Useful Polarization Properties



Semiconducting and piezoelectric nanosprings of zinc oxide synthesized at Georgia Tech. These nanostructures have potential applications as nano-scale sensors, transducers, and resonators. Photo courtesy of Georgia Institute of Technology.

Researchers at the Georgia Institute of Technology (**www.gatech.edu**) have developed a class of nanometer-scale structures that spontaneously form helical shapes from long ribbon-like single crystals of zinc oxide (ZnO). Dubbed "nanosprings," the new structures have piezoelectric and electrostatic polarization properties that could make them useful in small-scale sensing and microsystem applications.

Just 10 to 60 nanometers wide and 5 to 20 nanometers thick (but up to several millimeters long), the structures could be useful in detecting and measuring very small fluid flows, tiny strain/stress forces, high-frequency acoustical waves, and otherwise imperceptible air flows. When deflected by the flow of air or fluids, the nanosprings would produce small but measurable electrical voltages.

According to Zhong L. Wang, director of Georgia Tech's Center for Nanoscience and Nanotechnology, "They could be used to measure pressure in a bio-fluid or in other biomedical sensing applications. You could use them to measure nano- or pico-newton forces."

The piezoelectric properties could also make the structures useful as actuators in micro-systems and nanosystems, where applying voltage would induce strains. "In micromechanical systems, these structures could provide the coupling between an electrical signal and a mechanical motion," Wang noted.

The new structures also display unusual electrostatic polarization, with positively and negatively charged surfaces across the thickness of the nanoribbon. This electrical charge could be used to attract specific molecules, potentially allowing the nanosprings to be used as biosensors to detect single molecules or cells.

"The polarized surfaces will attract different molecules with different charges, which would permit selectivity," Wang said. "The nanosprings have the promise of being able to do single-molecule detection, because they are so small." Ultimately, he hopes the new structures could prove useful in biomedical monitoring applications; their small size may allow the development of tiny systems that can be implanted in the body.

Electricity from Tap Water

In the science of electrokinetics, it is well known that, when water travels over a solid material, the passage of its ions over the surface creates a slight electrical charge. But the charge is so minimal that, until recently, it was considered to be an effect with no potential practical applications. However, two engineering professors at the University of Alberta (**www.ualberta.ca**) have devised a method of extracting usable amounts of current from ordinary tap water by forcing it through many channels, opening up the possibility of powering cell phones, calculators, and other devices. Although the power generated by a single channel is relatively insignificant, the use of millions of tiny, parallel channels can dramatically increase the power output. So far, the professors — Dr. Daniel Kwok and Dr. Larry Kostiuk — have been able to boost the power output by about 2,000 percent, deriving enough energy to power LEDs. And they have high expectations for the process, even predicting that it may someday contribute energy to the commercial power grid.

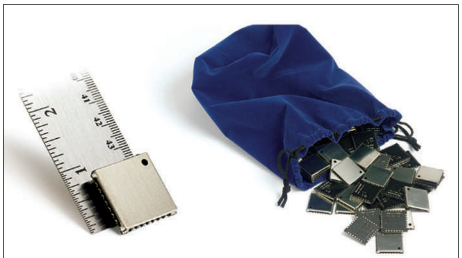
"This new technology could provide an alternative energy source to rival wind and solar power, although this would need huge bodies of water to work on a commercial scale," said Kostiuk. "Hydrocarbon fuels are still the best source of energy but they're fast running out, and so new options like this one could be vital in the future."

The environmental benefit of clean energy conversion using safe, renewable materials is motivating the team to explore how their prototype device may be developed into a battery for commercial use. The inventors are working with the University of Alberta's Technology Transfer Group (TTG) to develop a commer-

cialization strategy. A patent application has been filed by the university to obtain broad, early protection of the invention.

Computers and Networking

Transceivers for Small, Cost-Sensitive Applications



Aerocomm's AC4490-1x1 transceiver offers simple implementation. Photo courtesy of Aerocomm, Inc.

Developed for the short-range wireless market is the new AC4490-1x1 900MHz FHSS transceiver from AeroComm, Inc. (**www.aerocomm.com**). The one-inch-square module is a component for creating local RF networks where tight space, low power, and limited resources are the biggest concerns.

According to the company, engineers of varying RF experience can include wireless capability with minimal effort using the new device. All components, including firmware, are integrated into the multichip module design. Modules and antennas are simply mounted into place (via hand solder or surface mounted with automatic pick-and-place equipment), then powered on. No special host software is required; 1x1s appear to the system as cables.

The modules contain AeroComm's RF232 embedded protocol, which allows for plug-and-play installation. RF232 guarantees successful communication while making the process invisible to the OEM. Over-the-air issues are managed in the firmware to synchronize, hop, gain acknowledgements, send retries, detect errors, address messages, secure transmissions, and other features unique to RF that newcomers may overlook.

The 1x1's standard TTL serial interface provides bidirectional communication in point-to-point, point-to-multipoint, or multi-to-multi networks. A number of on-the-fly control commands accommodate varying wireless applications. Prime features include:

- Up to 115.2 Kbps serial interface data rate
- 1 to 10mW variable output power
- Local/remote I/Os: (2) digital input lines, (2) digital output lines, (1) A/D input line, and (1) D/A output line
- -40°C to +80°C industrial temperature durability
- Priced at less than $20.00 each in volume

The AC4490-1x1 is targeted primarily at industrial and commercial battery-powered applications such as meter reading, building controls, point of sale, and home automation. It can be used in portable, mobile and fixed applications in the US, Canada, Australia, and South America.

IBM Sells 20 Millionth ThinkPad

Late last year, IBM (**www.ibm.com**) announced that it had sold its 20 millionth ThinkPad® notebook PC, making it the best-selling notebook brand ever. Since its introduction in 1992, ThinkPad has delivered many "firsts," including the first notebook with a color LCD panel, 14-inch LCD, full-sized keyboard, and removable hard drive.

The 20 millionth IBM ThinkPad notebook is an Intel Centrino mobile technology-based system featuring 512 MB RAM, a 1.7 GHz processor, a 60 GB hard drive, and an extended battery life of up to 8.5 hours. This particular ThinkPad T41 is said to be one of the industry's thinnest and lightest 14-inch notebooks, at a little less than one inch thick and with a travel weight of 4.5 lbs.

IBM has sold 20 million ThinkPad notebook computers since 1992, making it the world's best-selling model. Photo courtesy of International Business Machines Corporation. Unauthorized use not permitted.

ThinkPad notebooks have been used in numerous Space Shuttle missions, under the oceans, and in chilling cold during several climbs to K2 and Mt. Everest. A ThinkPad notebook is also included in the permanent design collection of the Modern Museum of Art in New York.

Parenthetically, one could wonder if the purchaser of the 20 millionth machine might have received it for free in honor of the occasion. But, judging by company statements, he seems to have paid full price for it. No discount. No congratulatory party at Burger King with Miss Peoria and some helium balloons. Not even an IBM plastic pocket protector. Leave it to those party animals at IBM.

Intel Boosts Processor Speed for Low-End PCs

Providing good news for bottom feeders in the PC market, Intel Corporation has introduced a new Intel® Celeron® processor that runs at 2.80 GHz and is suitable for desktop and mobile PCs. Based on Intel's

0.13-micron process technology, the processor utilizes 478-pin packaging and features a 400 MHz system bus. In 1,000-unit quantities, the Intel Celeron processor at 2.80 GHz is priced at $117.00. PCs based on the new chip should be available by the time you read this.

Circuits and Devices

Circuit Building Blocks for Engineers, Students, and Hobbyists

A new product for developing electronic circuits — called Schmartboard — was introduced late in 2003. Available at electronic retailers such as R and D Electronics (**www.randdelectronicparts.com**) and on Schmartboard's website, the product is aimed at electronic engineers, engineering students, and electronic hobbyists.

Traditionally, an engineer might spend weeks designing a new layout, wait another week or two for production of a PCB, and spend a substantial sum on the prototype only to find out that revision is needed, after which the process begins again. Students and hobbyists might spend weeks working with wire-wrap boards. The Schmartboard, on the other hand, is designed to allow both professional and amateur designers to assemble a board in a matter of hours and make modifications to it as needed, eliminating the need to order a custom PCB or deal with wire-wrap boards.

Basically, the product consists of a variety of pretraced printed circuit boards that can be connected like building blocks, referred to as "electronic circuit building blocks." They allow the user to build electronic circuits on a SchmartBoard block by block, and then connect the blocks together to form a functional board. Because the boards are pretraced, the need for wire jumpers is minimized, in contrast to breadboards or wire-wrap boards. You can buy individual through-hole or surface-mount circuits, but Schmartboard also offers a 26-part combination pack for $49.95. Available accessories include mechanical bridges, headers, and jumpers. For details, visit **www.schmartboard.com**

Industry and the Profession

Wind Energy Center Opens

New Mexico's most ambitious wind farm — called the New Mexico Wind Energy Center — recently started producing electricity for the Public Service Company of New Mexico (PNM, **www.pnm.com**), the state's largest electric and gas utility. The center — the world's third-largest wind generation project — was officially dedicated in October.

Turbines spin at the New Mexico Wind Energy Center, located 170 miles southeast of Albuquerque and 20 miles northeast of Fort Sumner. Photo courtesy of Sandia National Labs.

Located 170 miles southeast of Albuquerque and 20 miles northeast of Fort Sumner, the wind center sits on 9,600 acres of private and state-owned land. The center consists of 136 turbine towers, each measuring 210 feet in height with turbine blades measuring 110 feet. It will have a peak output of about 200 megawatts of electricity, or about 1.5 megawatts per turbine. The turbines require 8 MPH winds to produce electricity and will continue to produce electricity in winds up to 55 MPH. The center is expected to produce enough electricity to supply 94,000 average-sized New Mexico homes.

Engineering Job Market Remains Weak

Although the unemployment rate for all workers fell slightly in the third quarter, the rate moved in the opposite direction for US electrical and electronics engineers (EEs), according to data compiled by the Department of Labor, Bureau of Labor Statistics (BLS, **www.bls.gov**). The jobless rate for EEs rose from 6.4 percent in the second quarter to 6.7 percent in the third, while the rate for all workers fell from 5.6 percent to 5.5 percent. At the same time, the number of employed EEs fell by 37,000 (from 386,000 to 349,000).

The 6.7 percent figure is more than six times as high as it was in 1997 (1.0), and more than five times as great as 2000 (1.2). The EE unemployment rate reached an all-time high of 7.0 in the first quarter of 2003.

Among other high-tech professionals, the unemployment rate jumped for computer hardware engineers (5.7 percent to 6.9), computer software engineers (4.1 to 4.6), and network and computer systems administrators (5.6 to 7.6). The rate fell for computer scientists and systems analysts (5.6 to 4.8), computer programmers (7.5 to 7.1), and network systems and data communications analysts (5.5 to 5.0).

For comparison, the third-quarter jobless rate for mechanical engineers rose slightly from 3.1 percent to 3.3 percent, while the rates for civil engineers (3.9 percent) and industrial engineers (5.9 percent) remained the same. **NV**

Electronic Theories and Applications From A to Z

Let's Get Technical

Traveling on a Beam of Light: A Fiber-Optic Communication System

Almost 2,000 years ago, I worked for a summer with one of my engineering technology students pulling a spool of fiber optic cable around the floor of my engineering building. My idea back then was to build a fiber optic intercom, using the fiber between laboratories to carry analog audio waveforms digitized using a simple pulse-code modulation technique.

Recently, I dusted off the project and made a few changes. Now, I have added some basic communication concepts to the project, and had my students design printed circuit boards to implement the electronics. Software has been written to control the hardware. This month, I begin a series of columns on fiber optic applications.

In Figure 1, you can see a block diagram of the full-duplex fiber optic communication link. Parallel data is input at each end of the link, converted into serial data over the fiber, and back into parallel data at the opposite end of the link. Full-duplex communication allows data to flow in both directions at the same time.

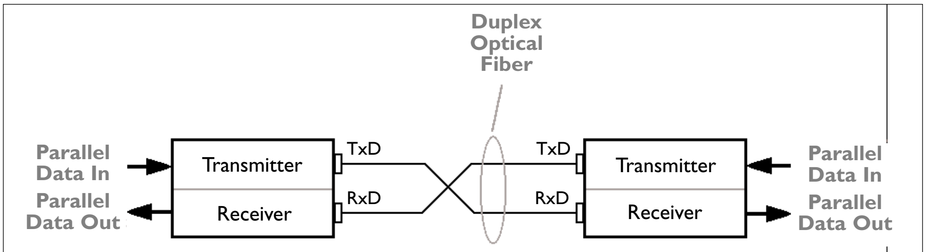
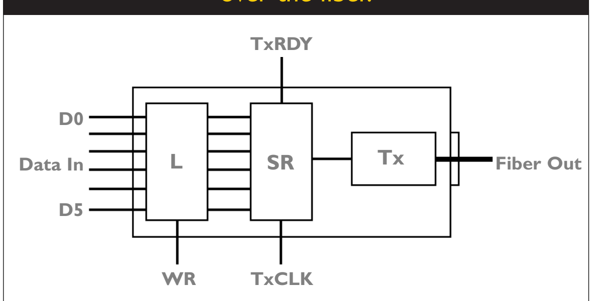


Figure 1. A fiber optic communication link allowing full-duplex communication between endpoints.

In order to make my students suffer through a complete understanding of the system, I deliberately kept the transmitter and receiver hardware simple. So simple in fact, that only six bits of data are exchanged between the transmitter and receiver at a time. This leads to an unfortunate situation and is the cause for my students suffering: How do you transmit a byte of data (eight bits) from end to end? The solution can be found in additional hardware or, in this case, through the use of software. We will see that a higher-layer protocol will handle the problem of eight-bit transmissions.

Figure 2 shows a block diagram of the fiber transmitter circuit. Six bits of parallel data on D0 through D5 are presented to the inputs of a latch (L). The WR (Write) signal is used to load the parallel data into the latch and start a transmission. The TxRDY signal is an output that indicates when the transmitter is ready to accept another parallel load. The data from the latch is presented to a shift register (SR), which outputs serial data to the fiber optic transmitter (Tx). The speed of the transmitter clock (TxCLK) determines the data rate over the fiber. The design keeps the fiber dark (transmitter Tx is off) when idle to save power.

Figure 2. A block diagram of the fiber transmitter. Parallel input data is converted to serial data over the fiber.



The fiber optic receiver block diagram is illustrated in Figure 3. Serial data from the fiber is converted back into digital form by the fiber receiver (Rx) and presented to the input of the shift register (SR), which converts the data back into parallel form. When all the bits have been received, the shift register hands them off to a latch (L) so a copy is available even after a new set of bits starts coming in. The six bits of received data are available on the D0 through D5 outputs. The Receiver Ready (RxRDY) output indicates when a new set of data bits have been received. RxRDY is reset when the RD (Read) signal indicates the data bits have been read from the latch.

The Receiver Clock (RxCLK) runs 16 times faster than the transmitter clock, for reasons that will become known when we examine the actual circuitry of the receiver.

How is the data actually sent over the fiber? Physically, as a series

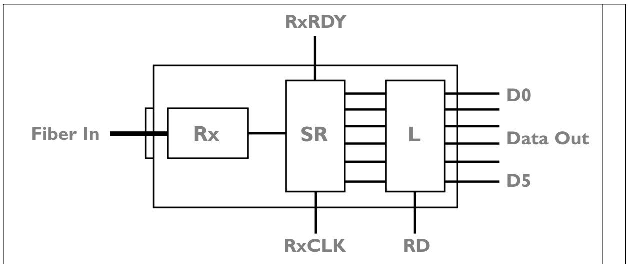


Figure 3. A block diagram of the fiber receiver. Serial data from the fiber is converted back into parallel.

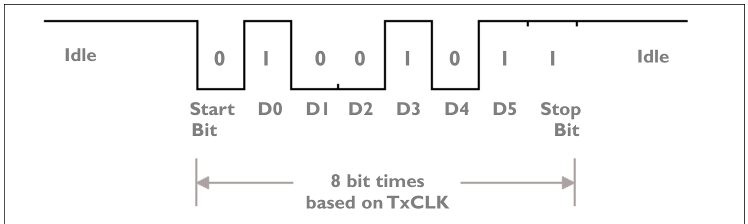


Figure 4. The format of a transmission frame.

of on or off pulses of light representing the bits, but with a specific order to the bits. In fact, two additional bits are added for framing, since this is an asynchronous communication link (there is no clock transmitted along with the data). These are the Start and Stop bits. The Start bit is always low and the Stop bit is always high. Figure 4 shows the format of the entire eight-bit frame of data that is transmitted.

Note that after the Start bit, the six data bits are clocked out in order from D0 (LSB) to D5 (MSB). The last bit in the frame is the Stop bit. This frame format is the digital waveform that is input to the fiber transmitter (Tx). When no transmission is taking place, the normal state of the idle signal is high. The fiber transmitter keeps the fiber dark during this time. Why have the fiber sitting there filled with light when nothing is being transmitted? This is also the waveform that comes out of the fiber receiver (Rx). So, you can see the importance of the Start bit being a zero. Whenever the signal goes low, we have the beginning of a new transmission frame. The Stop bit guarantees we return to the high, idle state of the signal when transmission is complete.

Now it is time for a little math. Suppose the transmitter clocks bits out at the rate of 1.25 Mbps (1,250,000 bits/second). This would correspond to a TxCLK frequency of 1.25 MHz. The following questions come to mind:

1. What is the time for a single bit?
2. What is the time for a transmission frame?
3. How many frames can be transmitted in one second?
4. How many bits of data can be transmitted in one second?

The time for a single bit is equal to the period of the TxCLK signal, which is the inverse of the frequency. So, the bit time Tbit is

$$Tbit = \frac{1}{TxCLK} = \frac{1}{1.25MHz} = 800ns$$

Since a frame contains eight bits, the frame time Tframe is:

$$Tframe = 8 \cdot Tbit = 8 \cdot 800ns = 6400ns = 6.4\mu s$$

The inverse of the frame time will give us the number of frames that can be transmitted in one second (Nframes):

$$Nframes = \frac{1}{Tframe} = \frac{1}{6.4\mu s} = 156{,}250 \text{ frames/sec}$$

You can get the same result by dividing the data rate by the number of bits in the frame:

$$Nframes = \frac{TxCLK}{8} = \frac{1{,}250{,}000}{8} = 156{,}250$$

The number of data bits (do not include the Start and Stop bits) that can be transmitted equals six times the number of frames/second, since there are six data bits in each frame. So, we have:

$$Nbits = 6 \cdot Nframes = 6 \cdot 156{,}250 = 937{,}500 \text{ bits/second}$$

Unfortunately, this is not the useable data rate we will obtain. Why not? That takes us back to the problem my students must struggle with. How do you send eight bits of data over the link? The answer lies in establishing a procedure for sending the eight bits of data using multiple frames. A communication protocol must be established to make this happen. Without going into any of the details right now, the chosen protocol requires that a group of three frames be transmitted to effectively move eight bits of data from one end to the other. Now, if we divide the number of frames possible in one second by three, we will get the number of groups possible in one second:

$$Ngroups = \frac{Nframes}{3} = \frac{156{,}250}{3} = 52{,}083.3$$

Since only a complete group is valid, we round down to 52,083 groups/second. Each group transmitted encodes an eight-bit chunk of data, so our actual data throughput is 52,083 times 8, or 416,664 bits/second. Clearly there is a lot of overhead (wasted bits) in this system.

In my next column, I'll cover the details of the group protocol, as well as the hardware designs of the transmitter and receiver. **NV**

About the Author

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College, with over 27 years of experience designing digital and analog circuitry, and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at antonakos_j@sunybroome.edu or visit his website at **www.sunybroome.edu/~antonakos_j**

Understanding, Designing, and Constructing Robots and Robotic Systems

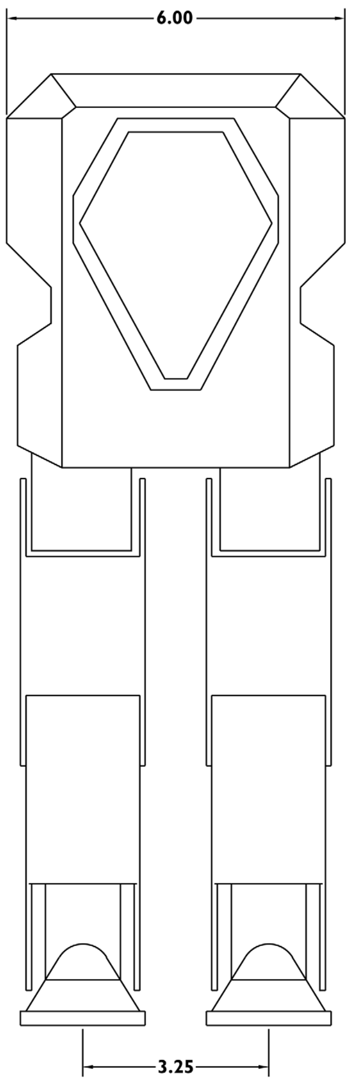
Personal Robotics

Instant Walker

When Dan Gates decided to build a walking robot, he set out to build "every man's robot," a robot that didn't require expensive machining or components, a walker that anyone could build. With only basic power tools, suitable research, and divine inspiration, Dan has created in three months what others fumble over for years. Part of his drive was what I think most of us have also perceived — a severe lack of research into humanoid bipedal robots with dynamic balancing. So, with some clever design, and craftsmanship, Dan created SAMM: the servo actuated mechanical man.

Personally, I have looked at the whole design of a walker as a series of difficult equations and pesky proportions. Masses to balance, forces to measure, dynamic formulae to grind over and discover. This is precisely why I have never built a successful biped (except in my mind). By taking a direct and intelligent approach, Dan has imbued the necessary functionality into his design by following a trail of success, extrapolating upon the valid elements, and simplifying the design.

Figure 1. Schematic of front

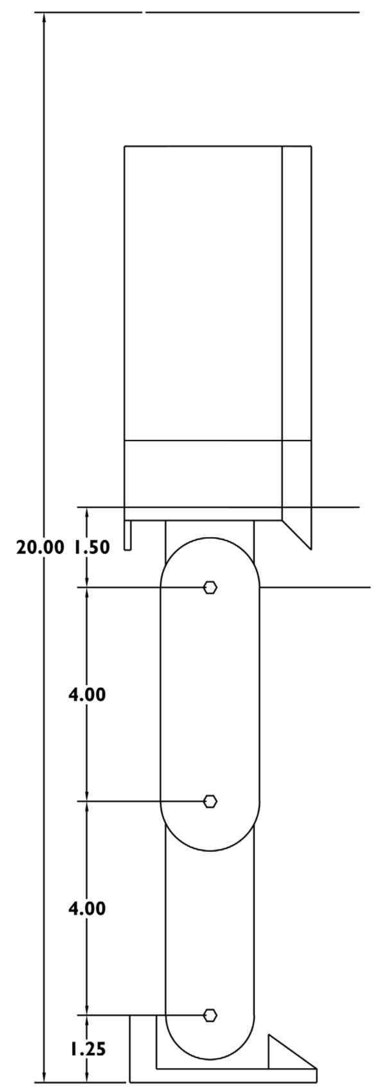


Tools, Materials, Techniques

With only acrylic plastic and thin aluminum sheet as materials, you couldn't ask for an easier shopping list. Commonly available at hardware stores literally everywhere, there should be no trouble finding these common materials. The key is in the construction; all it takes is a little intelligent planning, a reasonable degree of skill with only the most basic of tools, and a little intelligent forethought towards precision. Modeling component fits can be easily achieved with cardboard templates, and once the basics are designed they can be used as patterns that can be transferred to the material for cutting.

The first step is a 1:1 paper pattern of all the components required. CAD drawing and design techniques were deliberately avoided. Paper templates can be transferred to the

Figure 2. Schematic of side



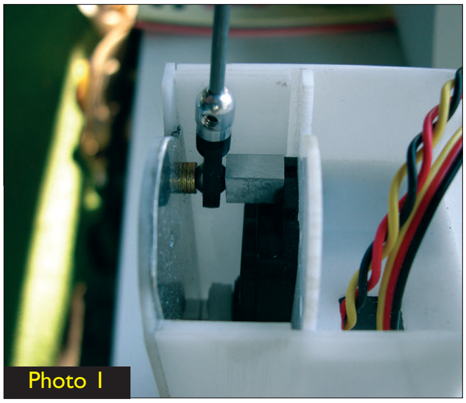


Photo 1

acrylic's paper backing, which is then rough-cut on a band saw or scroll saw. Identical components are sandwiched together with thin acrylic double-sided tape, and then stacks are sanded to a fine polish on a belt sander. Additional machining operations — like drilling or filing — can be performed at this time, as well. These techniques work equally well on thin sheet aluminum.

The Plan

Referring to medical texts, other robotics researchers, and even Leonardo DaVinci, Dan developed an overall proportional schematic to follow for the relationships of the joints. Subtleties such as the fact that a human finger segment length is 1.25 times longer than the one before were not overlooked. Literally building from the ground up, he developed the joint designs serially, starting at the ankle, and working up toward the hip.

Following the conventional robotic leg design of three degrees of freedom for the hip, two for the ankle, and one for the knee, SAMM has as many degrees of freedom as your standard research grade university robot. In Figures 1 and 2, the relative component lengths are shown to allow you to model your own walker on Dan's success.

Joint Task Force

Of critical importance in any mechanical system are the joints. The sliding, rotating, moving portions are a real deal maker/breaker. Ignore the frictional and loading forces, or the range of motions, and you will fail. Dan paid particular attention to these necessary details. Manufacturing accurate, yet simple hip and ankle joint linkage would have been a real chore, but many answers can be found at your local hobby shop.

These linkage parts must provide smooth, precise motions for a variety of craft traveling in excess of 60 MPH, and costing thousands of dollars. Using them in a small terrestrial biped may not have been in the hearts and minds of their manufacturers, but it is perfectly valid to adapt them to our own purposes.

Please notice the detail in Photos 4-7, showing the degrees of freedom in the hip and ankle.

Again, simple techniques and materials blend nicely with intelligent design to provide robust joints.

Motivational Forces

Again, looking toward the hobby market, we find every personal roboticist's best friend: the R/C servo. Over the last five years, Hitec has really straightened up their act, and now have a vast line of quality servos. Hitec is probably the choice of the discriminating roboticist, for selection, quality, price, and performance.

Utilizing Hitec's HS-645MG servos gave a reasonable balance between cost and function. These were used throughout the legs to accommodate the added stresses in this critical portion, without having to resort to the rather deluxe and pricey

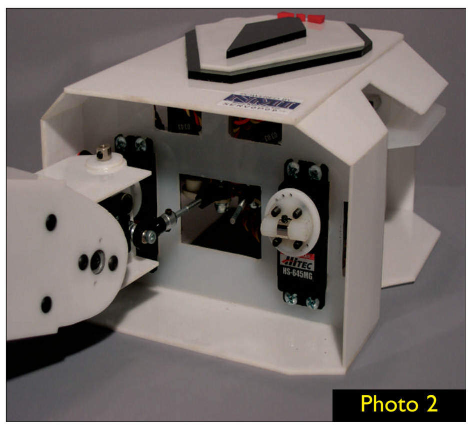


Photo 2

Table 1 - Suggested Tools

- Electric drill or drill press
- Belt sander
- Band saw
- Scroll saw
- Dremel™ tool
- Basic hand and hobby tools
- Basic drafting tools

- 1/16th inch acrylic
- 1/32nd inch aluminum
- Acrylic double-sided tape, not the foam type
- Weldon™ 3, Acrylic solvent
- Fine tip applicator bottle

- (12) HS-645MG servos for all leg joints
- (1) ServoPod
- (1) 9 V Lithium Polymer battery
- (1) 6 V Lithium Polymer battery

coreless, digital servos. Of course, these exist as an option, but why not use servos that cost 1/2 the price if they do the job?

Brain Pain

Originally, Dan considered Intel's X-scale controller as a basis for the brains behind the extensive brawns of SAMM. Development was estimated at several months to a year for all of the control electronics and software. That was before the ServoPod™ came along. At this point, just as Dan was nearing completion of Stage 1 of his mechanical platform, Randy Dumse, president of New Micros, Inc. (creator of the 'Pod line of robotics controllers and avid roboticist) came along.

With the addition of some custom software to provide smooth and accurate trajectory commands to S.A.M.M.'s 12 servos (soon to be at least 22 servos), Randy, in Texas and Dan in Oregon had SAMM walking in less than 10 hours. This, combined with Dan's three months of construction time, puts most of us to shame.

IsoMax™, the native language of the ServoPod, is a very efficient and innovative language. Coupled with the vast processing power and hardware capabilities of the ServoPod, Dan will be hard pressed to over task its DSP processor.

For those of us who wish to undertake such an endeavor, be sure to have the tools listed in Table 1 at your disposal. In the following months, Dan will be adding another 10 servos to motivate the head, shoulders, elbows, and hands.

Presently, there is more than ample torque to handle the planned mechanical expansion. Of course, there is much more to the story. At this point, SAMM is standing a proud 20" tall, and touting 22 axis' of motion will be capable of "walking," but not walking. The difference is responding to the environment.

In addition to the planned mechanical expansions, a bevy of sensors is also planned. Gyroscopes, an accelerometer, and force sensors for the feet are also waiting for their turn to be brought to life. Torque sensing on each joint is also within the realm of possibility.

Walk the Walk

Without the sensing, SAMM would have no idea what it was doing. It could be lying on its back, belly, or upside down, it simply would not know. With the addition of iner-

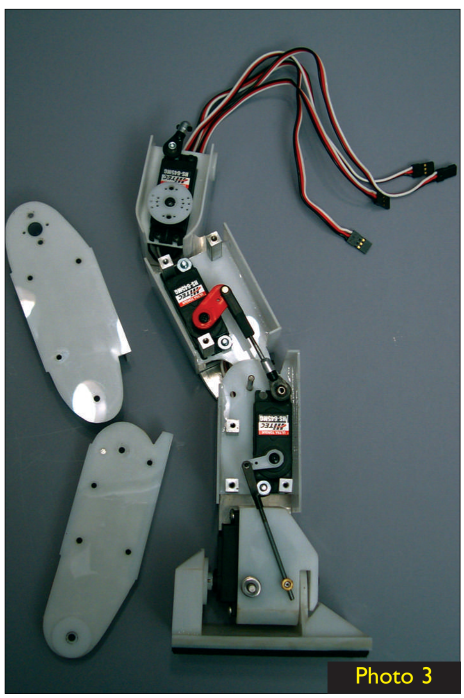
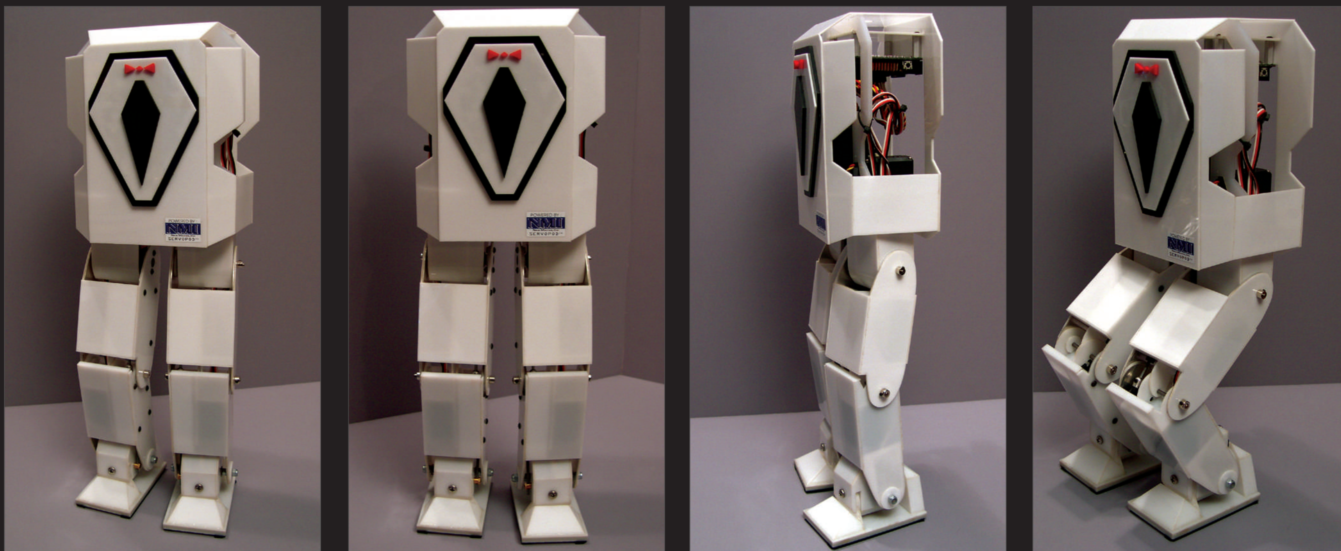


Photo 3

Photos 4-7 show the many degrees of freedom in the hip and ankle.



tial sensors, SAMM can be given a sense of balance and gravity to help keep it from tipping over. Pressure sensors on the feet will also help SAMM to respond to external forces, as well.

This is the basic recipe for a well-structured, humanoid biped robot, capable of accommodating varying terrain, not just running through "pre-canned" sequences like an advanced marionette. If you have seen videos of walking robots, you will find "dancers" and constipated "shufflers," SAMM will be a dancer in the extreme. In case you are interested, look up zero moment point on Google®. You will find the very essence of biped walking theory.

The ZMP is in effect the sum of inertial and gravitational forces. It tells you whether you will tip over or continue walking. Keeping your ZMP oriented properly is a very complex problem.

Fortunately, the ServoPods floating point math capabilities will make short work of these finer details, as well. So, overall, SAMM has met Dan Gates' vision of a simple to construct, inexpensive to build, un-tethered humanoid biped. With a little creativity, you too can follow this roadmap to mold SAMM into your vision of a biped, and benefit from Dan's experience. **NV**

Contact the Author

Dan Gates can be reached via Email at **dan@sorobotics.org**

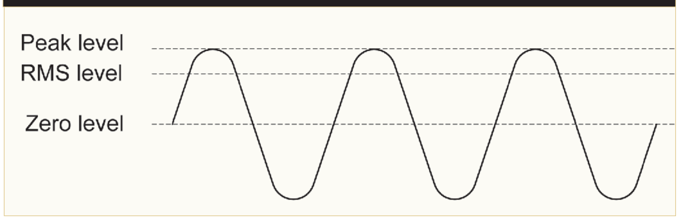
Basics For Beginners

Just For Starters

Easy Ways to Power Your Project

Every electronics project requires power to operate. Though power systems can get quite complex, many projects are well served with a few basic solutions. Designing a power system is easier when high voltages and currents are not required. Power systems are also simplified when the circuits being driven are not operating at high speeds and when components are not very sensitive to electrical noise. This article discusses power system design for a typical electronics project with low to moderate power needs. The techniques presented here can be applied in more demanding applications, though more analysis and care is required. A basic power system can be considered in three sections: raw power source, power regulation, and power distribution. Safety concerns dominate all three areas. This article stresses the use of off-the-shelf building blocks that reduce risk and design effort.

Figure 1. AC sine wave showing peak and RMS levels



Power Source

The most common forms of raw power available to most of us are the AC wall outlet and batteries. Solar cells run a close second for some and, for the purposes of this discussion, may be considered as batteries. AC-powered devices must somehow convert AC to DC because integrated circuits (ICs) run on DC. (Refer to the sidebar, "AC versus DC Power" for more information.) The conversion process is called rectification. Batteries, on the other hand, natively supply DC power.

AC-powered devices must also step-down the high voltage AC to a more manageable DC voltage.

In the US, AC power is nominally 110-120 volts. (AC power is nominally 220-240 VAC in Europe.) When was the last time you saw a logic chip run at 100 volts?! The step-down process generates a lower voltage that is not directly usable by ICs, but that is low enough for a voltage regulator to handle. Batteries offer less complexity here as well, because they are already low-voltage sources. Typical batteries have cell voltages from one to two volts, allowing you to combine as many as necessary to generate higher voltages. Working with AC is a safety headache. High voltages, step-down transformers, and rectifiers all pose problems that are best avoided. However, this doesn't mean that you should be restricted to batteries. A familiar "wall-wart" AC-to-DC power module is a great way to use AC power with all the high-voltage safety problems taken care of for you.

Wall-warts are available in varying output voltages and currents. Always make sure that the module is certified by Underwriters' Laboratories (UL) for safety. Whether you use a wall-wart or batteries, the power design task is made easier by working with low-voltage DC. It is easiest to select a wall-wart or battery configuration that provides the lowest practical voltage. If your voltage regulator requires 5.5 V, it is better to use a 6 V module rather than a 12 V module. We'll talk about a regulator's voltage requirements later.

Batteries

If you're using batteries, you have to determine how many are required based on the nominal cell voltage of each battery's chemistry. Alkaline batteries have a 1.5 V nominal cell voltage.

AC Versus DC Power

Direct-current — or DC — power is delivered at a static voltage. A battery provides DC power. Alternating-current — or AC — power alternates its voltage level between positive and negative polarity on each half of the sine wave.

Figure 1 shows an AC power signal that might be measured from a standard wall outlet. The 110-120 VAC nominal level is actually a mean value because the voltage is constantly changing. The nominal level of an AC sine wave is its root-mean-square (RMS) value. The RMS value of an AC sine wave is equal to the peak sine wave amplitude divided by one half the square root of two, or approximately 0.707 times the peak amplitude. A 120 VAC RMS level corresponds to a peak voltage of nearly 170 V. An AC power signal is rectified using diodes, or rectifiers, to achieve a constant polarity. Figure 2 shows a rectified version of the power signal in Figure 1. This rectified, but non-static signal is then filtered and regulated to provide a static DC power supply.

Rechargeable nickel cadmium (NiCd) and nickel metal hydride (NiMH) batteries have a 1.2 V nominal cell voltage. Multiple cells are stacked in series to provide higher voltages. If your regulator requires 5.5 V, that's four alkaline or five NiCd/NiMH cells. This is why some battery-powered devices cannot accept rechargeable batteries: they were designed for the higher alkaline cell voltage.It is also important to be aware that battery voltage varies with the charge left in the battery. This is in contrast to wall-warts that emit a narrow DC voltage range. A fully charged cell is typically several tenths of a volt higher than the nominal voltage. Likewise, the cell voltage droops as its charge is depleted. Therefore, the combined battery voltage of five 1.2 V cells may range from 7.5 down to 5 V before their charge is depleted. If the voltage regulator's minimum voltage is above the battery's minimum useful voltage, the system will cease operation before the batteries are fully depleted. In the case of NiCd and NiMH batteries, some people regard a 1.1 V cell voltage as the point where the cells are effectively discharged. Under this assumption, a five-cell NiCd/NiMH battery pack has a useful minimum voltage of 5.5 V.

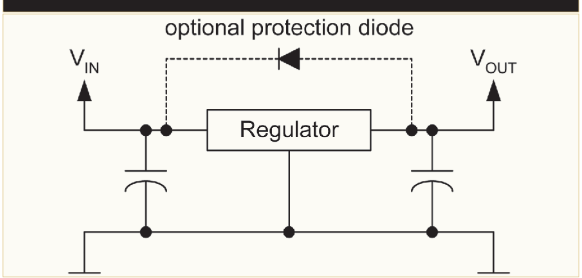
Figure 2. AC rectification

Fusing

Fuses are a recommended safety feature. A fuse is placed in series between one of the DC source's two leads (positive or negative) and your voltage regulator. You select a fuse with a particular current rating. The fuse will allow current to flow up to its rating. If the power system tries to draw more current than the fuse allows, the fuse will blow, or trip, and open the circuit. Fuses can prevent fires and other calamities by preventing damaging high-current discharges that can result from short circuits. If your system requires one amp, you may select a two amp fuse to provide adequate headroom so that the fuse doesn't trip if you go over your expected power consumption for a few seconds.

Wall-wart AC/DC modules should already have overload protection, but adding your own fuse is good practice. Batteries are potentially dangerous because they have no inherent current limiting feature. Low internal resistance is a desirable battery specification because it means that the battery will waste less power when you draw power from it. The battery will try to give you as much current as you ask for. Fusing is highly recommended because even a small battery can generate sparks and catch fire in a short circuit situation.

Figure 3. Basic linear regulator usage



Regulation

Wall-wart and battery voltages vary with time and load. Yet, electronic circuits generally demand tightly regulated voltage rails, often with tolerances of

±5%. A voltage regulator converts a varying input voltage into a relatively static output. There are numerous regulator circuits and components. The easiest and, arguably, the most reliable solution is to use an off-the-shelf integrated linear regulator. Linear regulators convert a higher voltage to a lower voltage by dissipating the difference as heat. This is not the most efficient method, but it works well for situations of low to moderate power consumption. Linear regulators work without hassle because they do not require many external components or careful tweaking and they do not produce noise as do switching regulators. They are a mature technology that has been around for decades and parts are made by numerous manufacturers.

Figure 3 shows how a typical fixed linear regulator is connected. The regulator has three terminals: input, output, and ground. (Some regulators are adjustable and contain an adjustment terminal in place of ground. More information on fixed and adjustable regulators is available in my book *Complete Digital Design*.) Capacitors on the input and output are per the manufacturer's recommendations. An optional discharge diode prevents the output voltage from significantly exceeding the input voltage when power is turned off. This protection may be required by certain regulators. A long-popular linear regulator family is the 7800, with the 7805 being a well-used 5 V device. These and newer regulators are manufactured by companies including Fairchild Semiconductor, Linear Technology, Maxim Integrated Circuits, and Texas Instruments.

Regulator Specifications

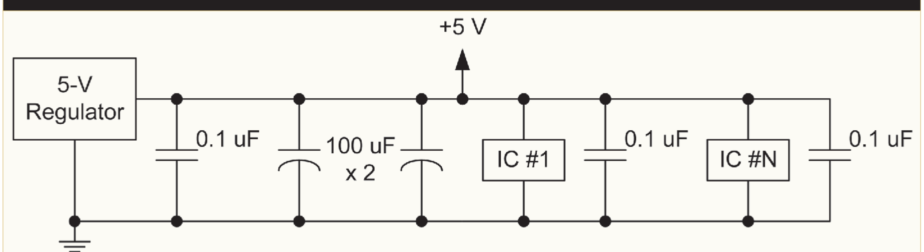
The major attributes to look for in selecting a linear regulator are power rating and drop-out voltage. Power rating is simply how much current and voltage a regulator can handle. Power ratings are dependent upon cooling capability, such as a heatsink, that you may provide. For low power levels of perhaps one watt or less, cooling may not be a concern. As you reach towards several watts, you should investigate thermal analysis and cooling to ensure a safe, working system. Drop-out voltage is the minimum difference between input (unregulated) and output (regulated) voltage that the device can handle. If the input falls below the drop-out voltage differential, the regulator cannot maintain the output within its specifications. Regulators are available with drop-out voltages from around 2 V to near 0 V. This is where a system's minimum required input voltage comes from. If you need a 5 V regulated supply and your regulator has a drop-out voltage of 0.5 V, the raw DC supply must not fall below 5.5 V. Low drop-out regulators potentially save power because they work with a smaller input/output differential. Remember that a linear regulator dissipates the input/output differential as heat. A smaller differen-

tial means less heat and a more reliable system. Of course, you must provide a low enough input voltage to take advantage of low drop-out power savings.

Power Distribution

Power distribution schemes vary based on the circuit assembly technology at your disposal. The best solution is to distribute power on a printed circuit board (PCB) with continuous copper planes for each voltage rail. This is the lowest inductance and resistance method. Power connections between regulators and planes should be with multiple vias to keep inductance and resistance low. If you are wiring a circuit by hand on a breadboard, try to minimize the distance that power must travel from the regulators to the other components. Longer wires increase inductance, which increases the circuit's susceptibility to higher frequency problems. Whether using a PCB or breadboard, adequate power supply decoupling is essential to minimize disruptive electrical transients that result from switching digital circuitry. A minimum decoupling provision is to place a high-frequency ceramic capacitor at the power leads of each integrated circuit (IC) on your board. A small capacitance — such as 0.1 µF — should be used so that the capacitor can be effective at the high frequencies generated by switching logic. It is equally important to minimize the wire lengths between each capacitor and its associated IC to reduce the inductance of the capacitor circuit. Longer wire lengths can nullify the beneficial effects of decoupling capacitors. Figure 4 shows a basic decoupling scheme for a small system. Each IC has a 0.1 µF decoupling capacitor. There are also a couple of higher-value "bulk" capacitors (100 µF) that provide lower-frequency decoupling. Voltage regulators have a finite response time to changes in current demand. The bulk capacitors help with these lower-frequency transient events. Exact values for the bulk capacitors are usually imprecise, especially given wide tolerances in components. Recommendations may be available from regulator data sheets.

Figure 4. Power supply decoupling



Safety

Safety considerations cannot be over-emphasized when dealing with power circuits. Proper fusing, insulation, cooling, spacing of components, and component selection should not be neglected in the haste to build your creation. It is always wise to conservatively de-rate components based on their power specifications. For example, if a component is to dissipate one watt, select a component that is rated for two watts. Building a safe, reliable power circuit is not difficult for small systems and will give you confidence in your project. **NV**

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high-tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design, Mark has actively participated in industry standards committees and has presented work at technical conferences. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at mark@completedigitaldesign.com

An attentive reader pointed out a mistake in last month's column on PCB design. The thickness of half-ounce copper was incorrectly listed as 0.006 inches, while it is actually one tenth of that, 0.0006 inches.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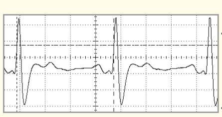

Enjoy learning about the inner workings of the heart while at the same time covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. Operates on a standard 9VDC battery. Includes matching case for a great finished look. The ECG1 has become one of our most popular kits with hundreds and hundreds of customers wanting to get "Heart Smart"!

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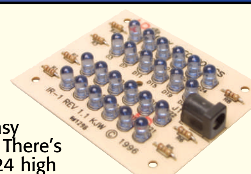

Imagine being able to see in total darkness! It's easy with any BW CCD camera and this IR illuminator! There's nothing magic about this kit - it's just an array of 24 high intensity IR LEDs and appropriate drive circuitry. The real magic is in the CCD video camera. CCD sensors are sensitive to IR light that you can't see, thus illuminate the scene with IR and the camera 'sees' just fine. The whole array will illuminate similar to what you'd expect of a bright flashlight.

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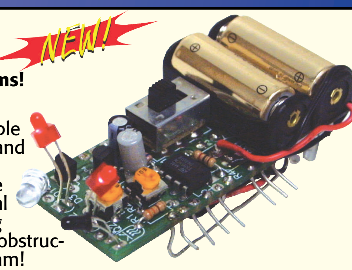

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ROGUE SIMPLIFIES DATA STORAGE

Rogue Robotics introduces the new uMMC™ (pronounced "micro MMC") serial data storage module. The uMMC module allows OEM designers and hobbyists to interface with SD and MMC data storage cards for multimedia, Internet, program storage, or data logging applications.

The uMMC module is a small (2" by 1.25") footprint board, providing an easy-to-use TTL serial interface for SD and MMC cards. Using the serial command protocol, designers can read and write data to FAT16 and FAT32 formatted cards, which can then be easily removed, inserted into other devices for data portability, interpretation, or modification. SD cards can also be locked for read only applications.

The uMMC can support SD and MMC cards from 8 MB to 512 MB in size.

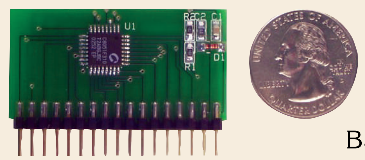
The uMMC module retails for US $59.95 (qty. 1) and only US $30.00 each (qty. 1,000).

For more information, contact:

ROGUE ROBOTICS
103 Sarah Ashbridge Ave.
Toronto, ON
Canada M4L 3Y1
416-707-3745 Fax: **647-439-1577**
Email: **info@roguerobotics.com**
Web: **www.roguerobotics.com**

Circle #109 on the Reader Service Card.

A MORE POWERFUL GADGET



AM Research has released a third member of the Gadget family, the Gadget310. Based upon the Cygnal C8051F310 microcontroller, this tiny, I/O-rich, Gadget sports a full 16K of parallel flash memory, 1,280 bytes of RAM, on-board temperature sensor, dual comparators, IIC and SPI interfaces, watchdog timer, a 10-bit A/D converter, plus up to 26 I/Os.

Utilizing a parallel architecture rather than the

traditional serial bottleneck of stamp-like products, speed improvements up to several orders of magnitude (>100x) are realized. A faster native instruction speed (24.5 MHz) and power saving modes provide a range of features not previously found in such a small package.

A very complete, professional, software development environment is available without cost. Forth, Basic, and Assembler are fully supported with a full range of tools such as a disassembler, single-step debugger, integrated editor, serial communications program, and a large library of routines.

The Gadget310 is available in single quantities for only $39.00 and in a Development system for $225.00, which includes a motherboard with prototyping area, serial communications, DB-9 adapter and serial cable, plus power supply and an assortment of other Gadgets.

For more information, contact:

AM RESEARCH
PMB 423, 1000 Sunrise Ave., 9B
Roseville, CA 95661
Tel: **916-780-7623**
Email: **support@amresearch.com**
Web: **www.amresearch.com**

Circle #133 on the Reader Service Card.

A SWISS ARMY KNIFE FOR THE COMPUTER TECHIE

The Disk Jockey is a "Swiss Army Knife" of a product for the computer techie in all of us. Whether you need to simply mount IDE disks to the desktop of your Windows or Macintosh computer via USB or Firewire for additional storage, or mirror two drives together for an automatic backup, the Disk Jockey is the only tool that you'll need to carry around in your bag of techno-tricks. The Disk Jockey works with raw IDE drives of any size. The Disk Jockey is also a portable, platform independent disk copy/cloning device that can do an exact sector-by-sector disk copy of a drive, including any hidden files or OS partitions. The cloning features of the Disk Jockey make it ideal for the do-it-yourself system integrator or the personal video recorder (PVR) upgrade hobbyist of the neighborhood.

The Disk Jockey can also be used for a variety of

Circle #92 on the Reader Service Card.

diagnostic tests including data compare between drives, hard disk spanning to create one logical volume, hard disk testing for bad blocks, and disk erase using either a one-pass erase or a three-pass erase per National Security Administration (NSA) standards. The Disk Jockey is perfect for the IT professional, computer consultant, self-proclaimed "computer guru" or for anyone comfortable putting their hands inside of their computer. The Disk Jockey carries a suggested retail price of $349.95.

For more information, contact:

DISKOLOGY
Tel: **916-645-3196**
Email: **sales@diskology.com**
Web: **www.diskology.com**

Circle #125 on the Reader Service Card.

ROTOVIEW™ SOLVES HANDHELD DISPLAY CHALLENGE

INNOVENTIONS, Inc., is now shipping its development system for RotoView™, a patented new technology that allows PDA and cell phone users to "tilt" their way around the small display screens found on these devices. With a RotoView-enabled PDA or cell phone, the user overcomes the display navigation challenge by simply changing the orientation at which the device is held.

"We demand that PDA and cell phone manufacturers pack more and more information into those tiny displays. Yet a critical problem remains: Navigating through a large amount of information, whether it's a map or spreadsheet, is awkward," said David Y. Feinstein, RotoView's inventor and President of INNOVENTIONS. "The RotoView Development System is a way for OEM manufacturers, product managers, and researchers to easily try out the RotoView technology and explore ways to best implement it."

Using the RotoView technology, the handheld device is entered into Navigation mode. During Navigation mode, the user tilts the unit left-right or up-down to see beyond the boundaries of the display. At any time, the user can exit Navigation mode to fix the display (the Fixed mode), then resume Navigation mode and continue to rotate the device to view the remainder of the screen.

"RotoView was invented to address the inherent limitation of mechanical switches for navigating small handheld devices," said Mr. Feinstein. "RotoView makes navigation simpler and more intuitive, eliminating the need for using two hands while navigating the device screen."

The RotoView Development System is available now for $195.00. Electronics hobbyists and students may purchase it for a discounted price of $95.00. The system includes a fully assembled board for the RotoView sensor module, a Windows-based software package that allows you to interface the module to your PC and emulate the handheld display, and a flexible USB cable. A RotoView add-on module for the Pocket PC will be available soon.

While it is targeted towards engineers and product line managers wishing to quickly evaluate RotoView

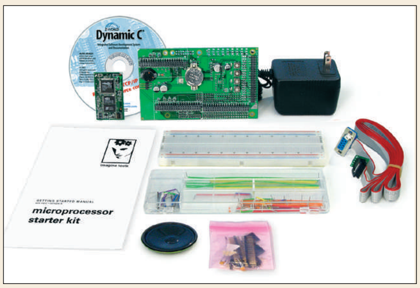
technology, the RotoView Development System is also perfect for electronics hobbyists, educators, and researchers in the field.

For more information, contact:

INNOVENTIONS, INC.
10425 Bissonnet St.
Houston, TX 77099
Tel: **281-879-6226**
Email: **scott@innoventions.com**
Web: **www.rotoview.com**

Circle #117 on the Reader Service Card.

THE MICROPROCESSOR STARTER KIT



Imagine Tools has launched its first product geared towards the electronics enthusiast and student: the Microprocessor Starter Kit. Taking an application-based approached for adding value to the product, several practical application notes can be downloaded from **www.imaginetools.com** for innovative uses of this embedded control system kit. Each application note has a wiring schematic, list of parts needed, sample C program to run the application, and an overview of what the application can do. These applications have been designed to challenge both the seasoned professional and the first-time electronics user. Applications can be expanded and/or used for learning how control systems work.

Imagine Tools plans to grow its business based on user-contributed designs. As the number and scope of applications increases, greater value is added to the Microprocessor Starter Kit for users to take advantage of. Imagine Tools is seeking to publish any practical or fun applications created by the user. Users whose applications are published on **www.imaginetools.com** will receive rewards based on the "cool factor" of the application, and the number of working applications from that particular user. Submission criteria are: a working application with wiring schematic, list of materials, sample C program, and brief overview of the application. To view the submission page, visit Imagine Tool's website. Let's see what you can do!

The Microprocessor Starter Kit is built around the Rabbit Semiconductor R3000 microprocessor. This eight-bit platform is designed specifically for embedded control systems and is also used in Rabbit Core Modules. The kit contains a starter board for prototyping and wiring various applications to the core module included in the kit. Dynamic C Lite is a free, simplified educational version of the industry proven Dynamic C Integrated Development Environment for use in the kit. This free C language compiler provides a simple interface to program and run applications. The Microprocessor Starter Kit is available for purchase at a special introductory price of $99.00 for a limited time at Imagine Tool's website.

For more information, contact:

IMAGINE TOOLS
2900 Spafford St.
Davis, CA 95616
Email: **info@imaginetools.com**
Web: **www.imaginetools.com**

Circle #140 on the Reader Service Card.

Electronics Showcase

Special products and services for the electronics enthusiast.

by Philip Kane

A Simple Wireless Audio System

Use Available Parts to Experiment With Inductive Signal Transmission

Wireless audio systems on the market today employ either RF or infrared technology. However there is a simple way to obtain acceptable voice quality wireless audio communication that doesn't use either of these technologies. In fact, you probably already have most of the required components. The rest are readily available and very inexpensive.

The block diagram in Figure 1 shows the basic elements of our simple wireless audio system. Notice that the transmitter is simply an audio amplifier (or radio, CD player, etc.). The receiver is a second audio amplifier. The receiver antenna is a small coil (such as a telephone pickup coil). The transmitter antenna is just a large loop of speaker wire. The transmitter signal can be received from inside of the loop and for a shorter distance outside of the loop. That's all you need to send and receive wireless audio signals!

How It Works

This is an example of an induction loop system. Its operation is based upon the fact that a current flowing through a loop of wire generates a magnetic field. Conversely, a changing magnetic field will cause a current to flow through, and thus a voltage to appear, across a wire that cuts the field. In the simple system described above, the changing audio signal at the transmitter generates a magnetic field around the transmitter loop. This field varies in direct proportion to the intensity and frequency of the transmitted signal. The voltage across the receiver coil will vary with the changing magnetic field. In other words the transmitter and receiver are inductively coupled.

Compared to RF signals, the magnetic field strength decreases relatively quickly (1/distance cubed) as the distance from the transmitter increases. However, what we lose in range we gain in simplicity. Low speed data transmission and voice quality communication systems can be implemented very simply. As a result, inductive loop systems find use in some interesting applications.

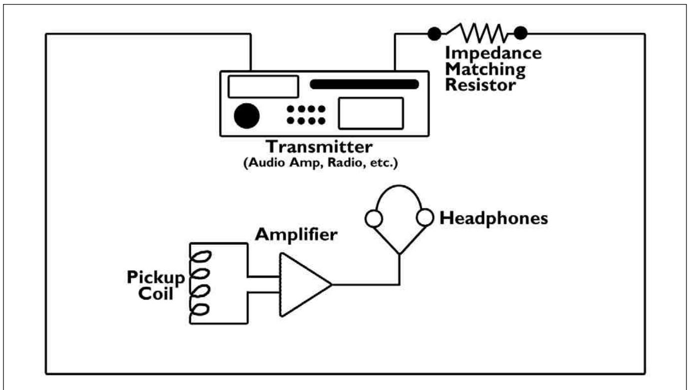


FIGURE 1.

Applications of Induction Loop Systems

Hearing Assistance

Go to Google or your favorite search engine and perform a search on the term "induction loop systems" or "inductive loop systems" (without the quotes). You will get over a thousand hits, most of which will be associated with the hearing assistance industry. This technology has been used to aid the hearing impaired for over 60 years[1]. In fact, hearing aids have for many years been equipped with a "T" switch which allows the user to switch between the hearing aid microphone and

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

tiny coil of wire, called a Telecoil. The Telecoil allows the user to hear audio signals being transmitted over an induction loop system (note that due to the trend towards smaller hearing aids and cochlear implants, Telecoils had begun to disappear from hearing aids in the US — but there has been a renewal of interest lately).

Short Range Communication Cave Explorers

Induction loop systems have been used by cave explorers as alternatives to RF systems[2]. Radio signals in the LF and VLF bands can propagate through rock, however they can require fairly large antennas. An induction loop system requires a relatively small loop in order to cover the short distance between the cave and the surface.

Short Range Data Transmission

Magnetic induction is being proposed as an alternative to RF and IR in a number of applications including wireless data transfer between computer peripherals, and wireless headsets for cell phones.

At least one company, Aura Communications (**www.auracomm.com/Technology**), has produced a chip set enabling designers to construct devices capable of short range communication using this technology. They have recently released a reference design for mobile telephone headsets named "Docker" that is receiving positive reviews in the press.

Constructing An Induction Loop System

In the remainder of this article we'll describe how to build a one-way voice quality induction loop communication system. It's intended to be a starting point for further investigation into applying this approach to creating low bandwidth short range communication systems.

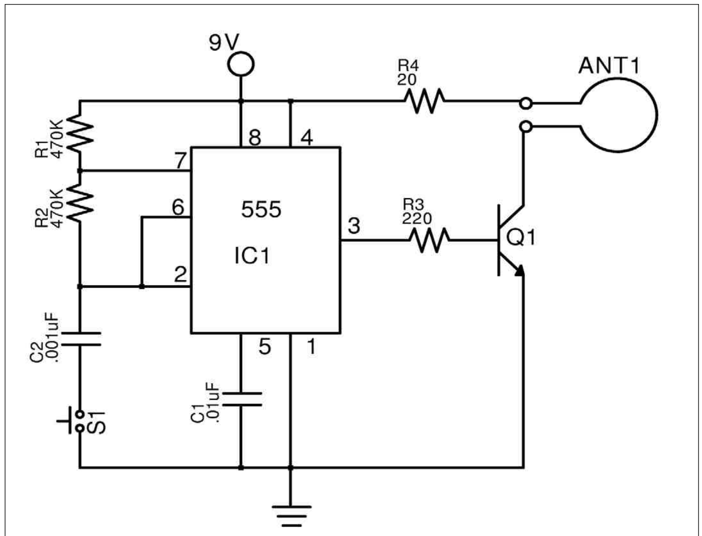


FIGURE 2. A Simple Signal Generator

C1	.01 µF capacitor
C2	.001 µF capacitor
R1,R2	470KΩ resistor
R3	220Ω resistor
R4	20Ω, 10 watt resistor
Q1	TIP31 NPN transistor (and heatsink)
IC1	LM555 timer IC
S1	SPST momentary contact switch

Getting Started

The easiest way to get started is to use an existing HiFi receiver (radio, CD player, etc.) with an external speaker connection, for the transmitter. The output power should be at least 4 W. Run a length of speaker wire around the room. Connect one end of the wire to the speaker output terminal of the amplifier.

The total impedance and power rating of the antenna loop should match that of the amplifier. For example, if the amp output is rated at 10 W into 8 ohms, then use an 8 ohm resistor with a minimum rating of 10 W, as an impedance matching resistor.

Connect the other end of the wire, in series with the impedance matching resistor, to the other speaker output terminal. The receiver can be a portable battery powered audio amplifier.

The receiver antenna is an inductive pickup coil which can be purchased from an electronics parts store. For example, RadioShack carries a telephone pickup coil (part# 44-533 in the 2002 catalog), and a battery powered amplifier (part# 277-1008) which are suitable for this project. To test the

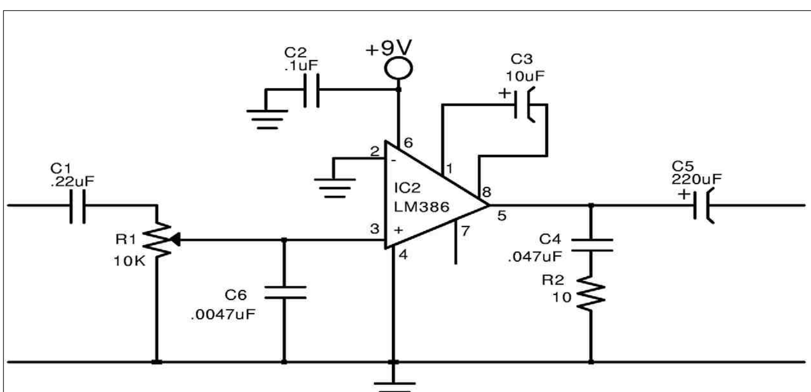


FIGURE 3. Audio Amplifier Module

C1	.22 µF capacitor
C2	.1 µF capacitor
C3	10 µF electrolytic capacitor
C4	.047 µF capacitor
C5	220 µF electrolytic capacitor
R1	10KΩ potentiometer
R2	10Ω resistor

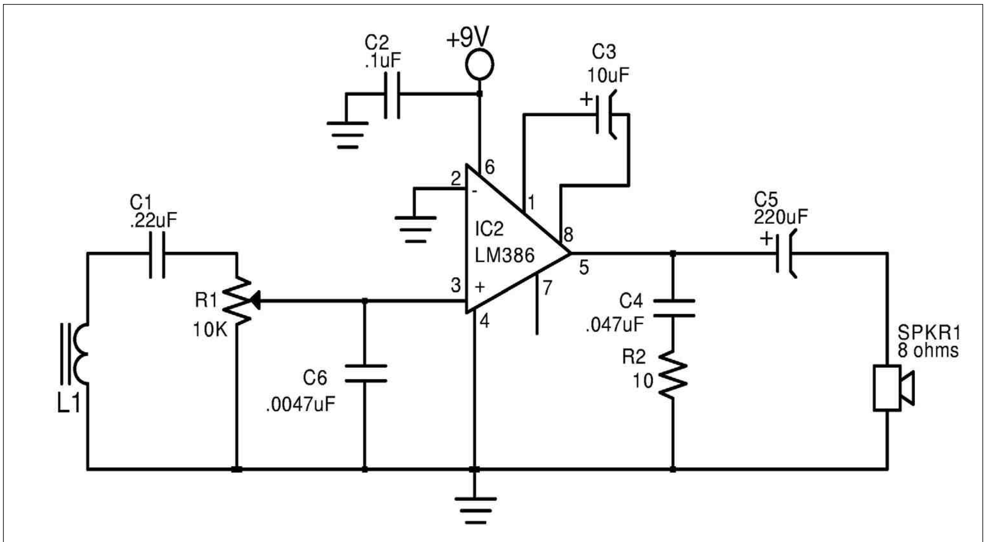


FIGURE 4. Audio Receiver

L1 Telephone pickup coil
(e.g., RadioShack part #44-533 in 2002 catalog)
SPKR1 8 ohm speaker (also see parts list for Audio Amplifier Module)

system, start by checking all connections. Make sure that the transmitter and receiver antennas are connected properly.

Place the receiver inside of the transmitter antenna loop and turn it on. Set the volume to half maximum. Next power up the transmitter and set the volume to minimum level. Gradually increase the volume until you can hear the transmitter signal at the receiver. If you notice power line interference try changing the orientation of the receiver antenna.

One note of caution. The impedance matching resistor can get very warm (even hot). Handle it carefully while the transmitter is operating. keep it away from material that is flammable or can easily melt.

Building Your Own System

It's easy to build your own simple wireless audio system from scratch. It takes few parts. They are readily available and relatively inexpensive.

Audio Frequency Signal Generator

To illustrate just how easy it is we'll start with the transmitter circuit in Figure 2. It's simply a 555 timer configured as an astable multivibrator. It generates a 1 kHz square wave signal which switches transistor Q1 on and off. Q1 drives the antenna L1 which is a loop of speaker wire in series with a 10 watt (minimum), 20 ohm power resistor. Remember the antenna needs to be long enough to encircle the area of coverage.

The transmitter has more than enough power to generate a signal that can cover a large room. You might be able to use it (along with the receiver described later) as a pager between adjacent rooms. Try taping the loop antenna to the wall separating rooms and see if you can pick up the signal in the other room.

Audio Amplifier Module

The circuit in Figure 3 is an audio amplifier circuit using an LM386. This basic circuit, combined with additional components, is used in the applications that follow. The LM386 s a very popular low power audio amplifier chip and is widely available at low cost. It requires a minimum of external parts, and has a wide supply voltage range (4 V to 12 V for the LM386N-1, the version used in this circuit). The voltage gain can be set anywhere between 20 and 200.

The gain for our amplifier is fixed and set to maximum, by connecting capacitor C3 between pins 1 and 8. Potentiometer R1 controls the output level. Input coupling capacitor C1 should be selected so that at the lowest frequency of interest its impedance is small compared to R1 (about one tenth of R1).

Bypass capacitor C6 may or may not be required. While working with this circuit I was getting significant interference from a local radio station (especially when the input was unconnected). Placing C6 between the input and ground eliminated the problem.

Note that the National Semiconductor data sheet for the LM386 indicates that high gain applications might require a bypass capacitor between pin 7 and ground. I found that it wasn't required.

Wireless Audio Receiver

To create a wireless receiver you simply connect a pickup coil to the input of the amplifier circuit and an 8 ohm speaker to its output, as shown in Figure 4.

Wireless Audio Transmitter

Figure 5 shows a simple wireless audio transmitter suitable for voice quality communication. The LM386 only provides about 1/4 W of output power. In order to beef up the power, add the emitter follower circuit formed by Q1, R3 and R4. Another option for the transmitter is to use a more powerful audio amplifier chip. One candidate is the LM384 5 W audio amplifier. Like the LM386, it

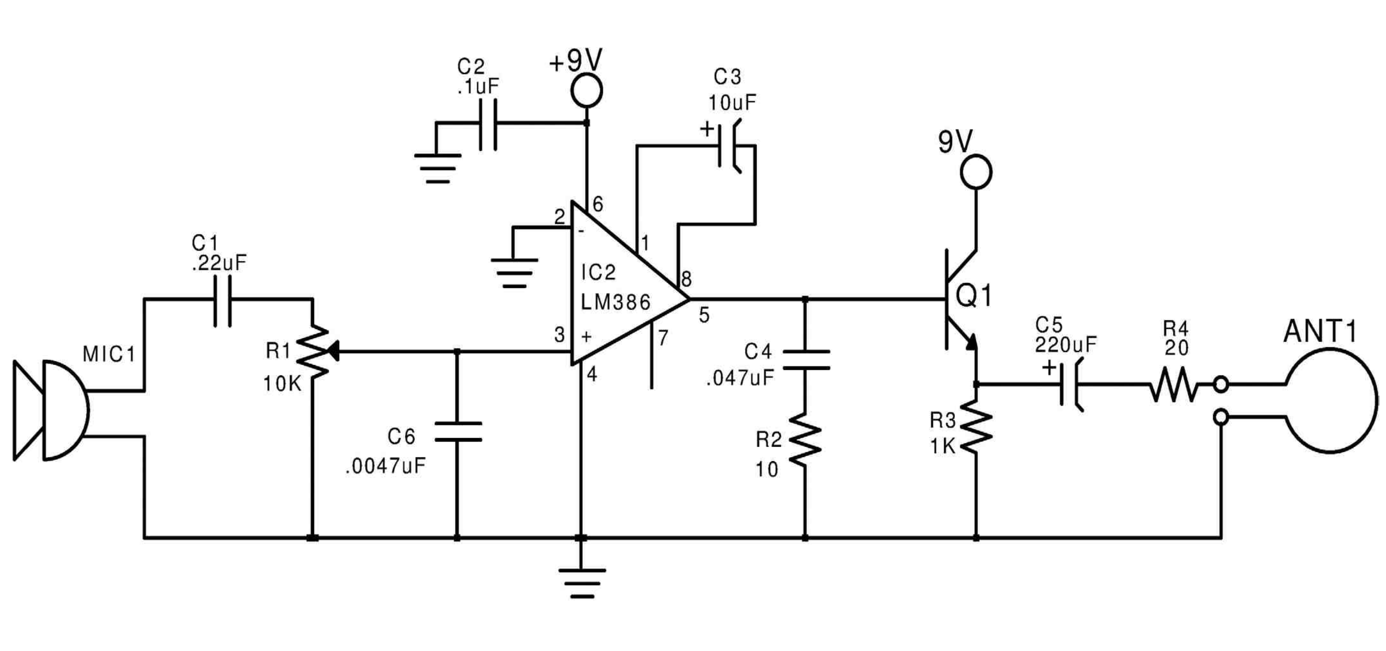


FIGURE 5. Audio Transmitter

R3	1KΩ resistor
R4	20Ω, 10 watt resistor
Q1	TIP31 NPN transistor (and heatsink)
ANT1	A length of speaker wire
MIC1	Microphone

(also see parts list for Audio Amplifier Module)

takes very few additional components to build a working amplifier.

The Antennas

As we described earlier, the transmitter antenna is simply a loop of speaker wire long enough to go around the perimeter of the area of coverage. Be sure to use an appropriate impedance matching resistor with the proper power rating. Remember to observe the handling precautions described earlier.

For the receiver antenna, you'll save a lot of time and effort if you use a telephone pick-up coil such as the one described above. Although we won't go into detail here, you should know that it is possible to make your own coils. I experimented with a few homemade coils ranging from an air core version made by wrapping speaker wire around a plastic tube, to winding smaller diameter wire around a ferrite rod. I had varying results depending upon the type of wire, number of turns, and type of core used. This is a good opportunity for some experimentation!

REFERENCES

1. *Looping the World: Rediscovering a simple and effective hearing assistance system*, by Paula Hendricks and Norman Lederman.
You can get it at:
www.ovalwindowaudio.com/articles/loopworld.htm

2. *Low Frequency Induction* Cave Radio Electronics Group
www.sat.dundee.ac.uk/~arb/creg/lfind1.html

Construction

The transmitter and receiver circuits are simple enough to be constructed using point to point soldering. Use general purpose prefabricated PC boards (purchased at most electronics suppliers).

This will help to reduce component wiring. In order to reduce power line hum, RF noise, etc., make sure that component leads and connecting wires are as short as possible.

The LM386 and LM555 ICs should be mounted in sockets as this eliminates the possibility of damaging them while soldering. Additionally, it's easier to replace an IC if it fails. Remember to observe the proper polarity for all electrolytic capacitors.

Conclusion

We've just scratched the surface in this article. There are a number of new ideas to investigate.

For example, there is communication over a modulated carrier, rather than the baseband system described in this article. Another idea would be a bidirectional voice communication system. A third would be short range data transmission for microprocessor based data acquisition systems. **NV**

by Tom Napier

Biassing G-M Tubes Isn't So Hard

A Minimal HV Generator Powers a Small Geiger-Müller Tube to Detect Ambient Radiation

Small Geiger-Müller (G-M) tubes make ideal sensors for pocket-sized devices to detect radioactivity. They have a high sensitivity to beta particles and some ability to detect gamma rays. Given a thin (and very fragile) mica window they will also detect alpha particles — most G-M tubes don't.

Still, even a small G-M tube needs an anode voltage in the 400 to 600 volt region. Here's how to generate that voltage from a 9 V battery. I first used this design in 1979 and I was pleasantly surprised to find that the parts are still available. I've even simplified things by driving the generator with a CMOS 555 timer.

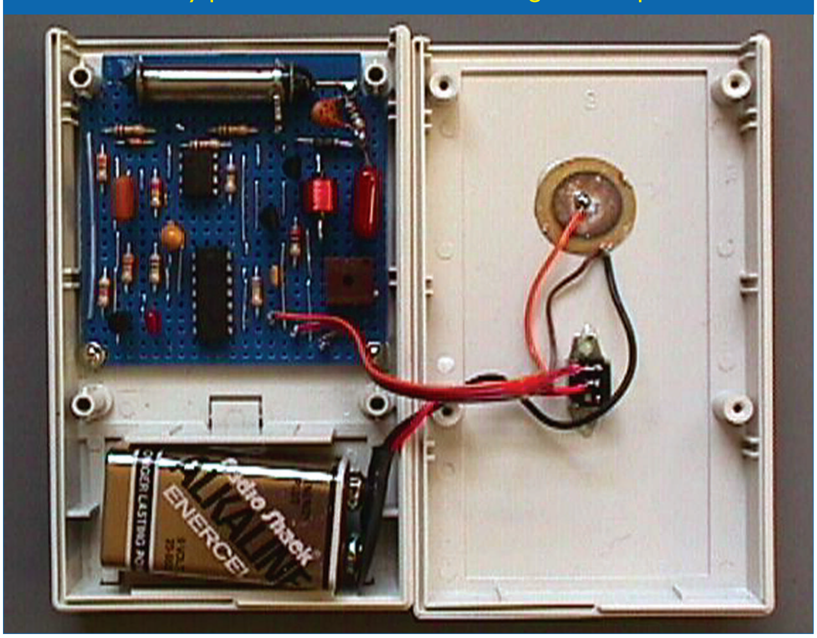
How Much HV?

Reference 1 gives a detailed description of how G-M tubes work. My detector uses a G-M tube 1.5-inches long and 0.3-inches in diameter. Its operating voltage is in the 400 to 500 V region but under normal conditions, it consumes virtually no current. Roughly speaking, each detected particle discharges the capacitance associated with the anode of the tube. Let's assume 450 V and 5 pF — that's 0.5 µJ of energy. At a background rate of one pulse every ten seconds, the mean current is just over 100 picoamps! In practice far more current goes to drive leakage than is needed by the tube. A rectifier with a microamp of reverse current is pretty good by ordinary standards, but would consume several thousand times as much power as the G-M tube! Even measuring the output voltage without drawing a disproportionate current would require a gigohm or so of sensing resistor and a very low bias-current amplifier. Therefore, we are much better off using a fixed-ratio converter and some well-chosen components.

Flyback Fun

In DC-DC converter handbooks, you'll find the flyback converter described as a constant-power device whose output voltage, unless stabilized, varies greatly with the load resistance. Each switching cycle delivers the power stored in an inductor to the load. Either the peak inductor current, or the switching frequency, is adjusted to maintain a constant voltage. What is less well known is that when the load current is low enough, a flyback converter behaves as a constant voltage source. It converts the peak inductor current to output voltage in a ratio that depends only on the inductor and the capacitance associated with it. This transimpedance ratio is the square root of L/C, and with practical components, can exceed 20 kV per amp. A 450 V output, for example, requires a peak inductor current around 20 mA. You can generate a stable high voltage with no transformers or voltage multipliers, just an inductor, a switch transistor, a rectifier and a reservoir capacitor.

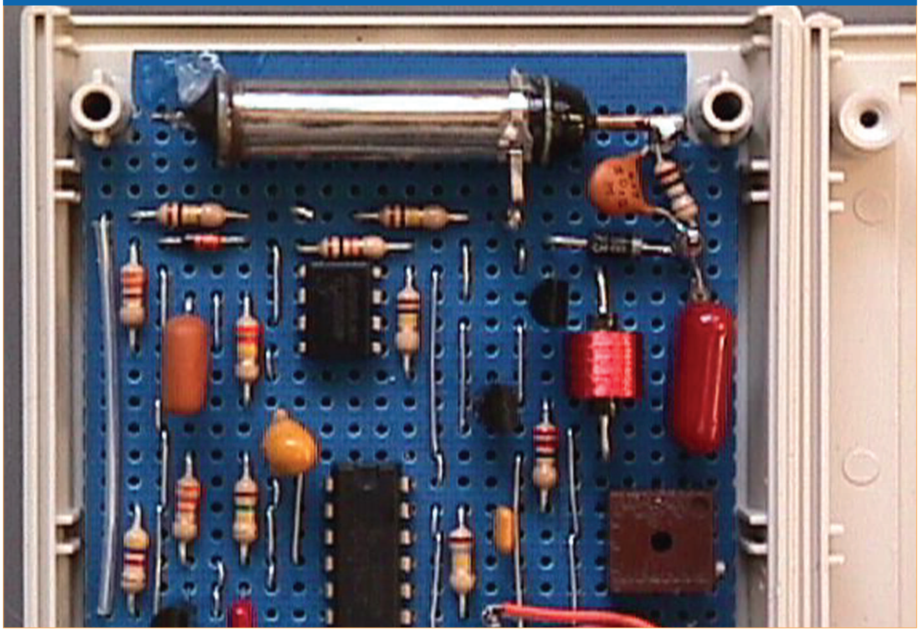
PHOTO 1. Everything fits easily in a small project box. The on/off switch is the only panel control, and above it is glued the piezo element.



A Practical Circuit

Figure 1 shows my implementation of this

PHOTO 2. A close-up of the prototype constructed on perf-board. The G-M tube fits across the top edge.



elegant converter. The CMOS 555 timer (U1) free-runs. Its on-time is about 30 µS, its off-time about 3 mS. The off-time is controlled by an RC network, and the on-time is set by the peak inductor current. The current is adjusted by VR1 to set the output voltage.

When the theshold current is reached, Q2 resets the 555. C2 then discharges through R1, eventually causing the 555 to retrigger. R1 is chosen to set a pulse rate that supplies sufficient output current while minimizing battery consumption. To avoid temperature drift, C2 should be a stable foil component, not ceramic.

When the output of the timer is high, C2 recharges rapidly via R2 and D1. At the same time, Q1 is turned on, causing the current through it and the inductor to rise by about a milliamp per microsecond. Q2 senses when the current reaches the preset value (around 25 mA).

This resets the timer, its threshold input is unused, and turns Q1 off, creating a positive half-sine-wave spike about 2 µS wide, and over 400 V high at the junction of the transistor and the inductor. D2, a fast high-voltage diode, passes this spike to C3, a 0.01 µF 630 V capacitor, to generate the G-M tube's anode supply. Since the output current is very low, the capacitor voltage remains constant.

The 555's discharge pin clamps Q1's base to ground. This not only achieves a rapid switch-off but also protects Q1 from high voltage breakdown. The negative half-cycle of the inductive spike is clamped via the collector-base diode of Q1.

The output voltage is directly proportional to the peak inductor current and is independent of the battery voltage.

The peak current is stable apart from a slight temperature coefficient so the circuit maintains a constant output without feedback from the output. Besides, G-M tubes are not fussy about their exact supply voltage. Despite the high peak current, the mean load on the battery is about 0.5 mA, giving several hundred hours of use.

Detecting Particles

The anode of the G-M tube is fed via a 10 M resistor, R6. This has a 4.7 pF capacitor (C4, rated at 630 V) across it. When a beta or gamma ray is detected the tube avalanches. The capacitor charges rapidly, dropping the voltage on the tube and giving a

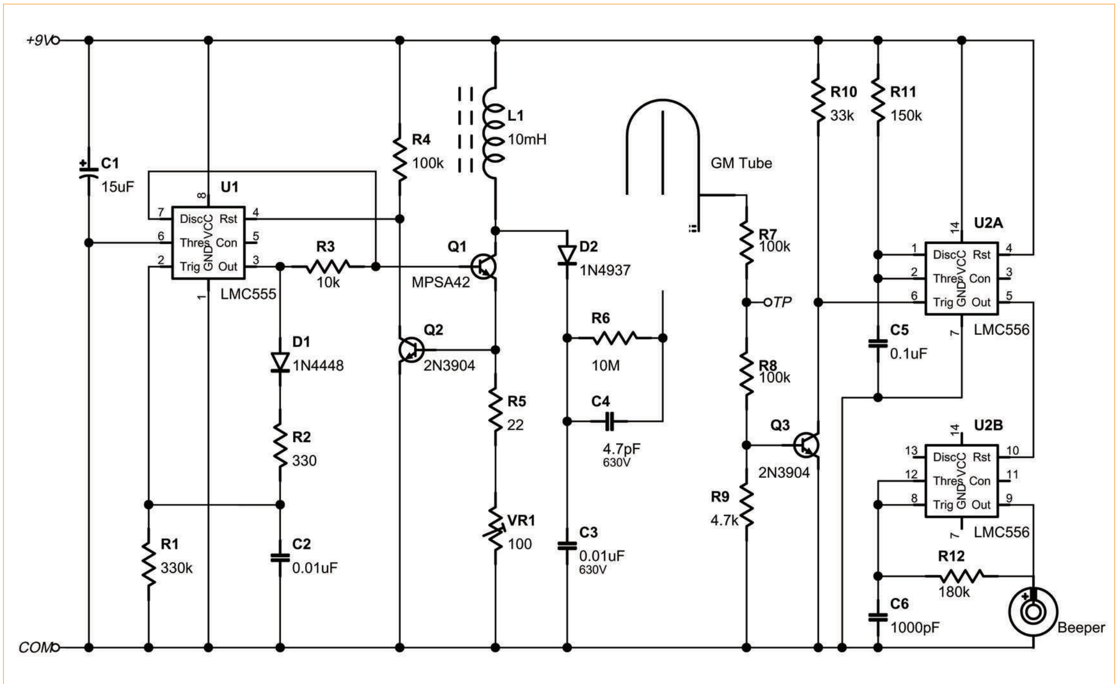


FIGURE 1. Take advantage of that pesky inductive turn-off pulse to power a Geiger-Müller tube. A dual timer makes a beep for every beta or gamma ray detected.

rapid quench. As the tube's own capacitance is about 1 pF, C4 defines the charge delivered by the tube.

Each particle detected generates a 5 µS pulse up to 100 V high at the G-M tube's cathode. Two 100K resistors between the cathode and ground protect the counting circuit and provide a protected test point. Q3 turns on for about 3 µS for each pulse. The output pulses drive a 556 dual timer. One half lengthens the pulse to 10 mS and gates the other half, a 3.5 kHz oscillator.

This drives a piezo-electric buzzer, making a beep for each particle. (My buzzer came from a broken calculator but Digi-Key part 102-1126-ND should do.) The pulses on Q3 can also drive a frequency counter to measure the mean radiation level. In my area natural background radiation produces about seven beeps per minute; Colorado residents may get twice that rate.

Radiation Levels

The absolute calibration of the detector depends on the tube size and type, and on the particle type and energy. I calibrated the G-M tube in my original detector with a known Cs137 gamma source. At 100 µRad/H, its count rate was 68 per minute. Since the tube is much more sensitive to beta particles, a given count rate corresponds to a much lower beta dose rate. A high count rate indicates either that something is badly wrong in your neighborhood or that a small source is very close to the tube. The latter, of course, is how you test that everything works.

Distance is important. A source can generate a horrendous dose rate on contact yet, because of the inverse square law, be relatively harmless a few feet away. When my work required handling radioactive sources, my rule of thumb was never to touch one bigger than 10 µCi with my fingers. I used tweezers or tongs instead. Bear in mind that radiation damage is more or less cumulative. (Exactly how much so is still hotly debated.) A source that is harmless in normal use should not be kept in your desk drawer all year.

Putting it Together

The HV generator uses two fairly rare components. One is a dust-cored, wave-wound 10 mH RF choke. The other is an MPSA42, a high-voltage transistor in a TO-92 package. Digi-Key stocks them both as well as the 1N4937 600 V fast recovery rectifier. Don't be tempted to substitute a 1N4005, it's far too slow.

Also stick with the wave-wound inductor, more conventional inductors could have too high a self-capacitance and might break down when generating around 500 V. I used Digi-Key part M7103-ND. HV capacitors are harder to find. If you can't find 630 V parts, 500 V ones should be safe enough. (A 0.5-inch square of double-sided PC board makes an adequate 5 pF HV capacitor.)

The MPSA42 transistor is rated at 300 V but during the HV pulse its base is grounded and the higher, collector-base, breakdown voltage applies.

I don't have the maker's figure for this but testing a sample showed no detectable current below 480 V and only a microamp at 500 V. (Allied Electronics sells the 400 V MPSA44 but I haven't tried it.) In any case the worst that can happen is that the maximum available output voltage will be limited to the transistor's breakdown voltage. You can get a good feel for just how high a pulse voltage you're getting by putting a times-ten scope probe on the collector of Q1. The 15 pF added by the probe reduces the output voltage significantly but its 10 Meg resistance has no effect at all. (Scope probes are usually rated for 600 V input but it would be as well to check.) If you want to measure the output voltage directly you'll need a meter with a better than 100 Meg input resistance.

I've no idea who made my G-M tubes. In 1979 my

then boss at CERN, the European accelerator laboratory, was throwing them out and I grabbed them. Similar ones do exist, see Reference 1.

Mechanical Stuff

This project fits a 2.75-inch by 4.6-inch plastic box with a compartment for a nine volt battery (e.g. PacTec HML-9VB). Everything except the buzzer and the on/off switch goes on a small PC board with cutouts to clear the box's molded pillars.

If you cut notches into the bases of the front two pillars and slip the board into them only two screws are needed to lock the board in place. Two #2 nuts glued to the bottom of the case act as stand-offs. The switch and buzzer mount inside the lid. Photo 1 shows the box layout.

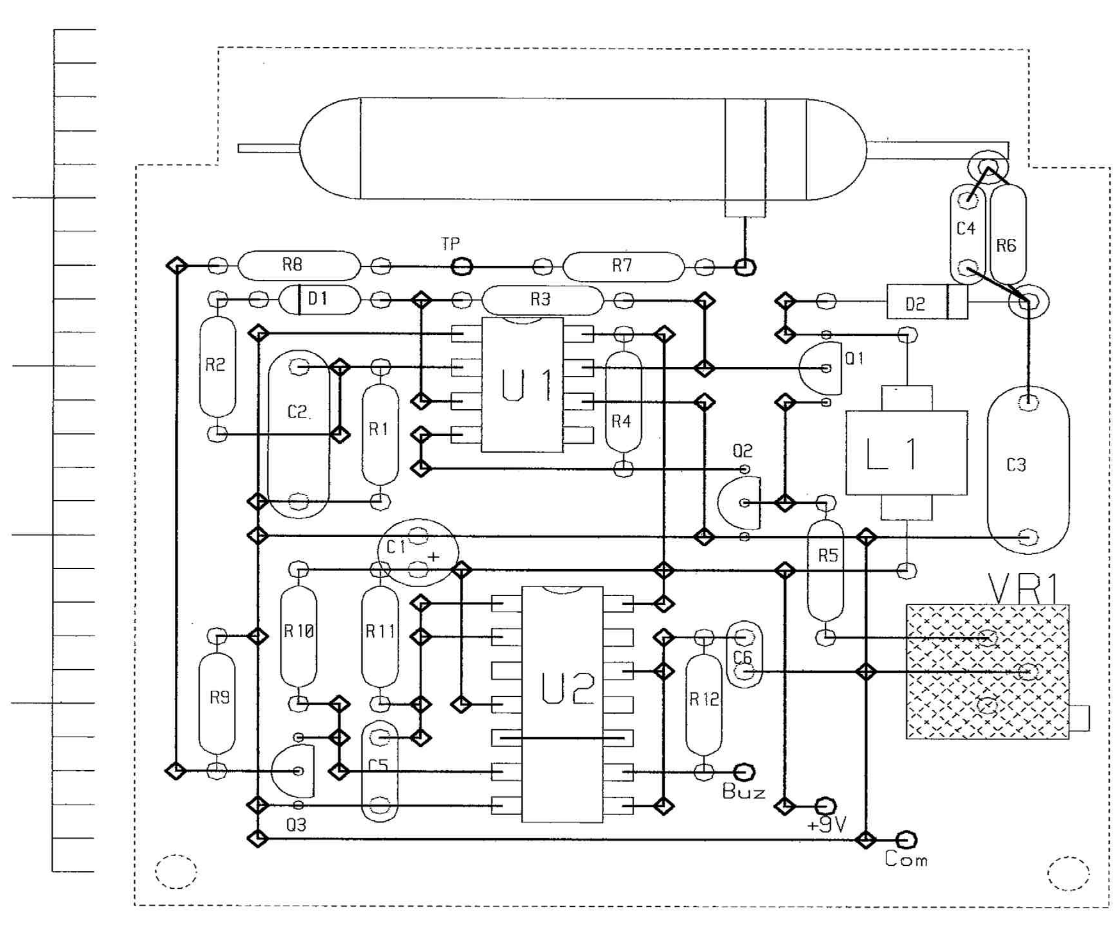


FIGURE 2. The prototype G-M counter was built on a small piece of perf-board whose component side is shown here. Thick vertical lines are bus wires on top of the board, horizontal lines are copper traces on the underside. Diamonds show where a wire connects to the copper. Editable schematics and a PCB layout are available for download on the *Nuts & Volts* website at **www.nutsvolts.com**

For maximum sensitivity the Geiger tube is mounted near the top edge of the box. The detachable end panel of the box should be left off or replaced by thin celluloid, it stops a significant fraction of beta particles.

A socket removed from a female Cannon-D connector slips nicely over the anode pin of the G-M tube. The cathode connection on my G-M tube is a little metal strap. A dab of silicone rubber stops it moving around. Two more tiny dabs on the glass ends of the G-M tube attach it to the board. (Its metal walls are a bit thin to glue to.)

Photo 2 and Figure 2 show the board layout. As is my normal practice, I used perforated prototyping board with copper strips on one side.

REFERENCE 1. Detailed G-M tube information.

The (G)Eiger Sanction
by Tom Dahlin, *Circuit Cellar* #150, January 2003

To cut back on leakage I put two Teflon insulated terminals through the board, one for the tube anode and one for the rectifier cathode. The HV components are wired between them. Even so, the tube voltage wilts on hot humid days.

It's important to keep the stray capacitance at the hot end of the inductor as low as possible. I cut away unneeded copper strips under L1 and D2. Wiring the outside end of the winding to +9 V reduces the effect of capacitance to near-by components.

One connection doesn't show on the board layout, a bus wire on the underside of the board that grounds the unused copper strips under the G-M tube. This stops the HV pulses coupling into the input of the beeper circuit.

Setting Up

The standard way to set the working voltage of a G-M tube is to apply a variable voltage and to plot the counting rate with a radioactive source present.

The plot should show a curve which rises from zero, levels off for a while then starts to rise again. The center

TABLE 1. The output pulse shape varies at the Geiger threshold. A pulse height about twice the threshold level is a good guide to the best operating voltage.

Pulse height	Applied voltage	
5 V	360 V	
10 V	370 V	(threshold)
15 V	390 V	(above threshold)
20 V	410 V	
25 V	440 V	(operating point)
30 V	470 V	
40 V	525 V	
50 V	580 V	

PARTS LIST

Semiconductors

U1	LMC555 timer
U2	LMC556 dual timer
Q1	MPSA42 high-voltage NPN
Q2	2N3904 or similar NPN
Q3	2N3904 or similar NPN
D1	1N4448 or equivalent
D2	1N4937 HV, fast-recovery rectifier

Passives

L1	10 mH wave-wound inductor
C1	15 µF 20 V tantalum bead
C2	0.01 µF plastic foil
C3	0.01 µF 630 V
C4	4.7 pF 630 V
C5	0.1 µF ceramic
C6	1000 pF ceramic

R1	330K (All resistors 1/4 W)
R2	330Ω
R3	10K
R4	100K
R5	22Ω
R6	10M
R7	100K
R8	100K
R9	4.7K
R10	33K
R11	150K
R12	180K
VR1	100Ω ten-turn trimmer

Misc.

0.8-inch Piezo buzzer
Slide switch
Prototyping board
Project box

of the "plateau" is the optimum operating point. Unfortunately, hanging a voltmeter on the converter takes far more current than the G-M tube.

The alternative is to look at the output pulse (TP in Figure 1) on a scope. If you see variable height pulses around 10 V high you are below the plateau. There the pulse height is proportional to particle energy.

The onset of avalanche is easy to spot. Some pulses will start off small, then suddenly burst out into a much higher pulse.

Adjust the trimmer until all the pulses show a consistent height; with my tubes this was about 12 V. Note this new peak height then adjust the high voltage until the pulses are twice as big, say 25 to 30 V. Table 1 shows the results I found.

One thing to watch is that the voltage changes quite slowly, particularly when adjusting it downwards. Make small trimmer adjustments and wait ten seconds or so for the pulse height to stabilize.

I Name My Sources

Testing G-M tubes is easier if the count rate is higher than background. Small (1 µCi) radioactive sources are available commercially but cost around $75.00 each.

I've used a Wyoming dinosaur bone as a source — they absorbed uranium as they fossilized. My two inch piece of rib generates about four counts per second when placed next to the tube.

If you want to create a stir you could try prowling around your local science store with a Geiger counter checking for "hot" fossils. Other common home-made test sources are objects made from yellow-tinted glass or china-ware with a bright red glaze.

If more than twenty years old these may contain enough uranium to drive most detectors off-scale. Try your local thrift store. My most powerful source is a thirty-year-old packet of colored glaze left over from an attempt at jewelry making.

One interesting experiment is to put a beta source a fixed distance from the G-M tube. Check how the count rate changes as you interpose different thicknesses of aluminum or plexiglass.

A thick enough sheet, about half an inch, will filter out all the betas, leaving only gamma rays. **NV**

Easy Ethernet Controller

Glue a PIC to a Full-blown Ethernet Transceiver

The Microchip PIC is an incredible device. Many PICs support multiple communications protocols natively. These protocols are normally used to talk to another equally equipped device or another PIC.

For instance, the PIC16F877 is a flash-based PIC that includes a Synchronous Serial Port (SSP) that supports Master Mode SPI and Master/Slave I2C. SPI is a 3-wire Motorola inspired protocol and I2C is a Phillips creation. You know these protocols well as they are often used to interface the PIC to EEPROMs, temperature sensors, and real-time clock ICs.

The PIC16F877 also sports a Universal Synchronous Asynchronous Receiver Transmitter (USART). If you've ever done anything with anybody's computer, you've used a USART, or its cousin the UART to perform RS-232 communications between the PC and a modem. The PIC's USART is one of its greatest strengths as the USART interface is used to make contact with serial devices on other computers or USARTS on other PICs. The PIC designers have not ignored the parallel port either. The PIC16F877 can be configured to deploy an 8-bit wide Parallel Slave Port on its PORT D pins.

All of the aforementioned PIC communications hardware is easy to invoke as the low-level firmware needed to make them function is built into the PIC itself. What if I could show you how to easily add Ethernet and thus Internet capability to the PIC's communications protocol resume? How would you like to control a remote device (or devices) on a LAN or across the Internet using standard communications programs found on your desktop PC?

If you've made it to this paragraph, you're interested and if nothing else, curious. So, here's the deal. EDTP has designed a simple module that completely exploits Ethernet functionality. Using this Ethernet module, a Microchip PIC16F877, a MAX233 or Sipex SP233ACP RS-232 IC, and some minor supporting components, I'm going to show you how to get your PIC16F877-based Ethernet controller on a LAN or the Internet for around $40.00 depending upon how much you can pull from the old "junk box."

Most PIC projects assume you have a PIC programmer. I'll eliminate the need for a PIC16F877 programmer and make arrangements to supply the PIC16F877 preprogrammed with BootLoader code.

The BootLoader will allow you to use a simple terminal emulator like HyperTerminal to load operating code into your PIC-based Ethernet controller. If you already have a programmer that will burn a PIC16F877, that's gravy and you can bypass ordering a preprogrammed PIC16F877, as I'll supply the BootLoader code via a free download from the EDTP website at **www.edtp.com** In addition, every "bit" and "byte" you need to implement the UDP and TCP/IP protocols for control purposes will also be available as a free download from the EDTP site.

Basically, through a deal with the folks at EDTP, I'm going to provide everything you will need to build this project from scratch from their website. For those of you that require a preprogrammed PIC16F877, I'll make that available also, in addition to the Ethernet module in kit form or assembled and tested. The idea is to make this easy. With that, let's get started and I'll show you how to build and operate your own Easy Ethernet Controller.

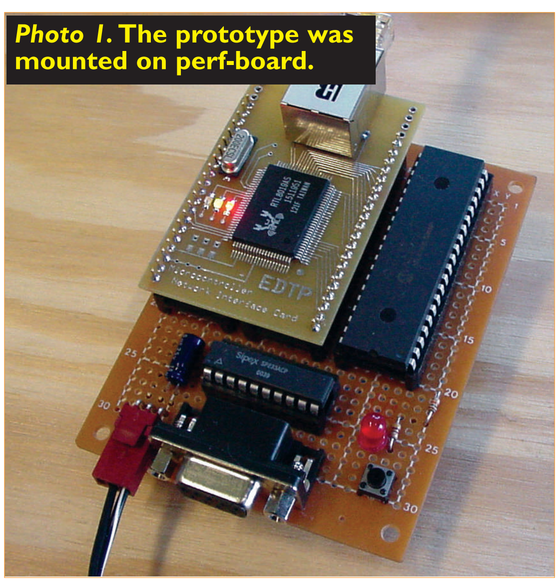
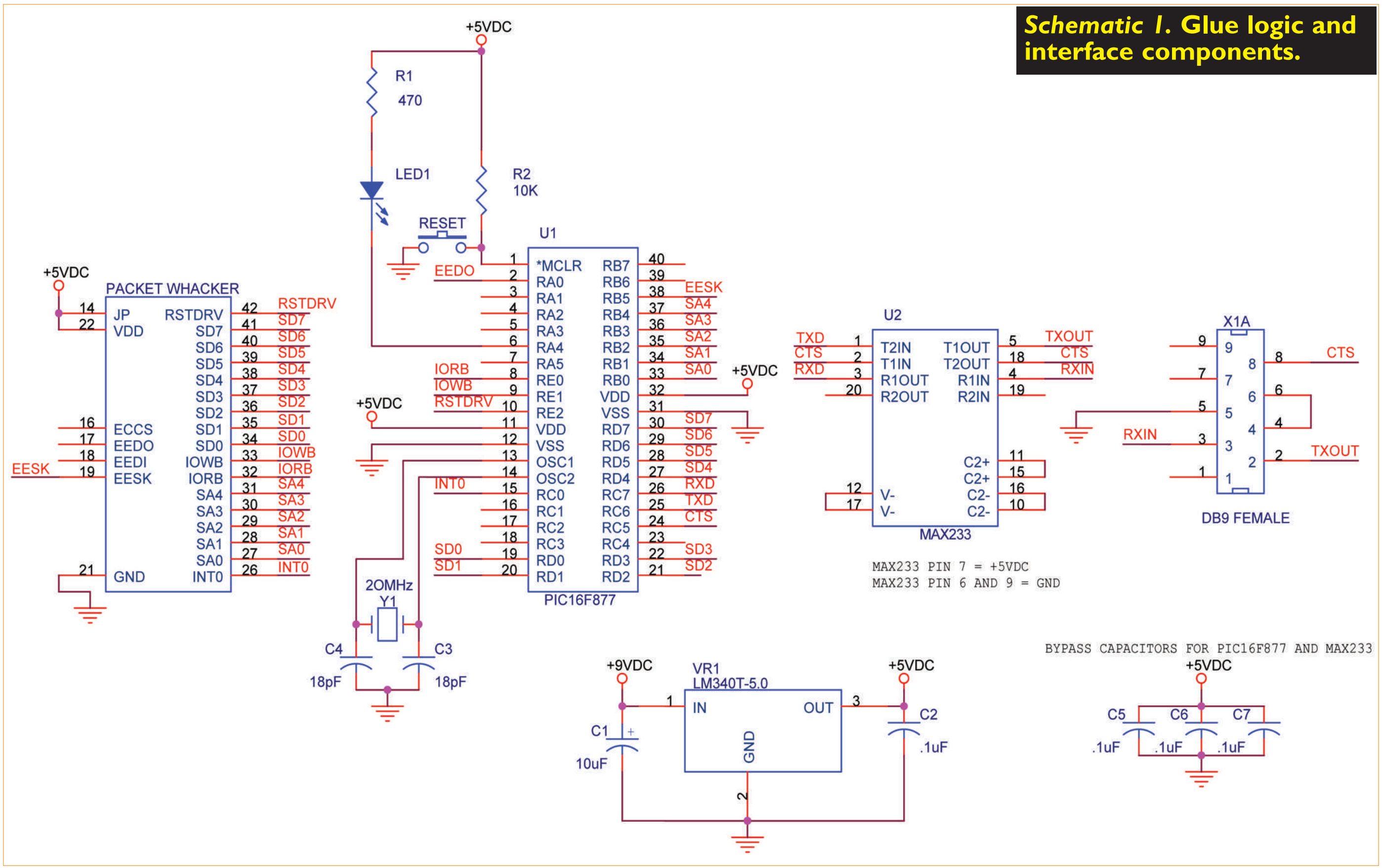


***Photo 1.* The prototype was mounted on perf-board.**

The Easy Ethernet Controller Hardware

As you can see in Photo 1, I built my Easy Ethernet Controller using wirewrap techniques mixed with some point-to-point wiring and surface mount technology on a standard perf board I got at my local



Schematic 1. Glue logic and interface components.

RadioShack. Building an Easy Ethernet Controller entails interconnecting three major components, a PIC16F877, the Easy Ethernet Controller module, and a MAX233 or Sipex SP233 RS-232 converter IC. Taking a look at the Easy Ethernet Controller schematic, you can see that there are no surprises in the serial interface design and the PIC is doing just what PICs do. The simple nature of this circuit is made possible by the Ethernet componentry onboard the Easy Ethernet Controller module.

The Easy Ethernet Controller serial port is used by the BootLoader to download PIC executable code into the PIC16F877's flash program memory.

Once the desired PIC firmware is loaded and running, the serial port is freed and can be used by the application that was just downloaded. For instance, an application taking orders from a Telnet screen on your PC can use that data to send a message or control sequence out of the Easy Ethernet Controller serial port. On the flip side, a device can communicate with the Easy Ethernet Controller through the Easy Ethernet Controller's serial port and the application running on the Easy Ethernet Controller could route that data to the Telnet session.

To load and communicate with

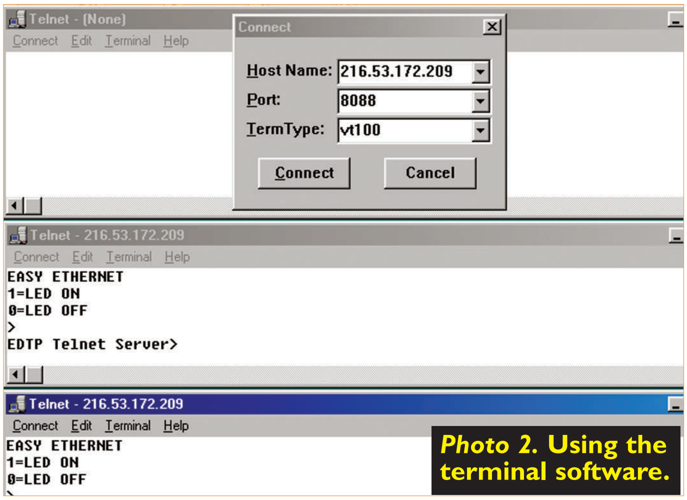


Photo 2. Using the terminal software.

the Easy Ethernet Controller, you'll need a good terminal emulation program for your PC. The best of them is free and it's called Tera Term Pro. You can download Tera Term Pro from their site on the Internet and from many of the shareware and freeware download sites.

I suggest using Tera Term Pro 32 for Windows NT/2000 and the standard 16-bit Tera Term Pro if you're running Win98. HyperTerminal will work as well but Tera Term Pro actually displays the download progress whereas HyperTerminal looks dead while the download process is running. Another plus for Tera Term Pro is that is can be "programmed" using a built-in scripting language to automate its operation.

After the Ethernet module is tied into the PIC16F877's I/O, there are still enough PIC I/O pins left over to use for things like analog input and digital output.

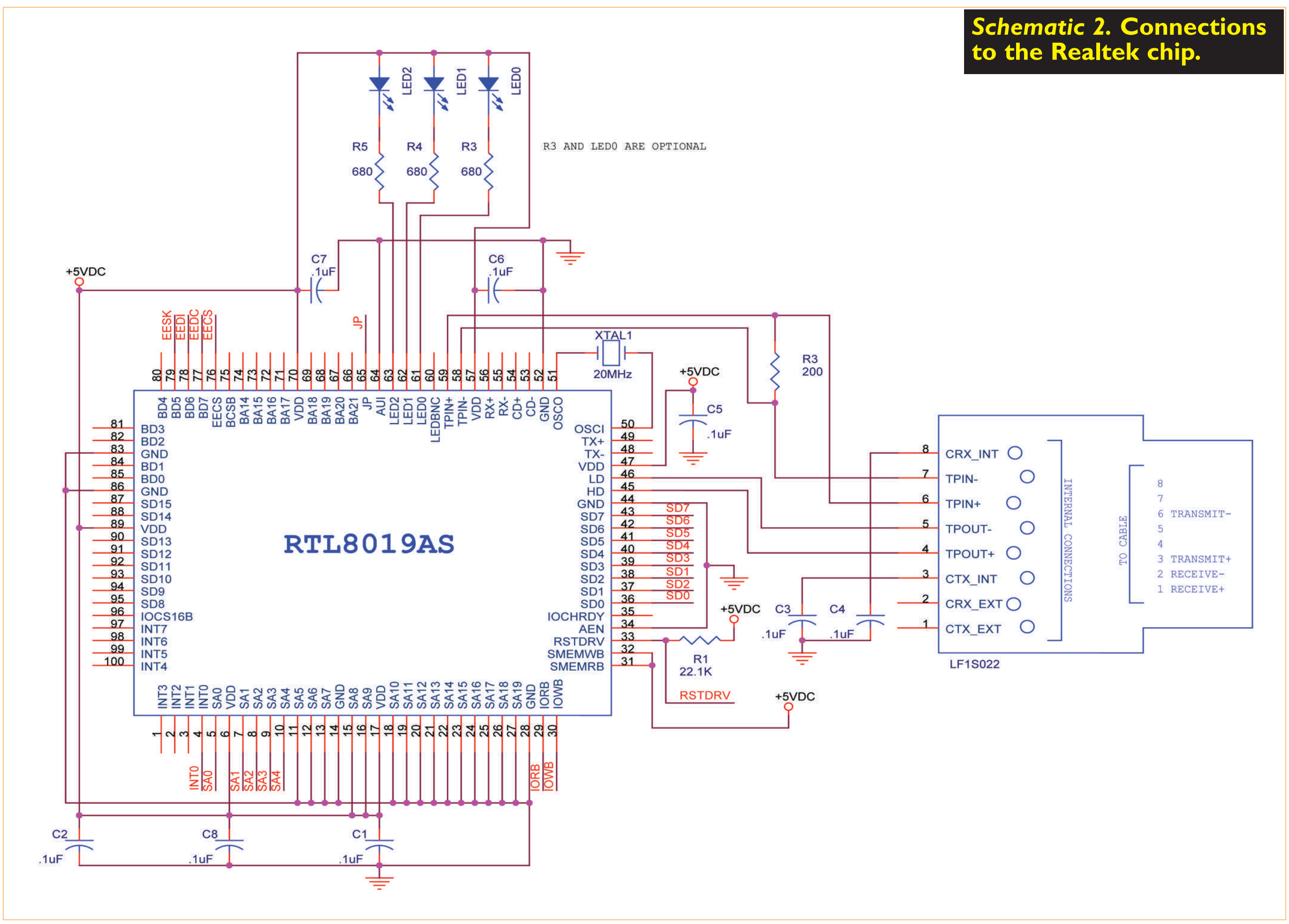
The pins that interface to I2C devices are also clear, allowing you to add such things as temperature sensors, real-time clocks, EEPROM, LED and LCD controllers, and additional I/O ports, just to name a few.

The PIC pins SA0-SA4 are used to address the RTL8019AS's internal registers and can do double duty when they aren't talking to the RTL8019AS IC.

For instance, Microchip sells a demo board that uses these pins to access a standard LCD module when they are not addressing the RTL8019AS.

So, even though it looks like the PIC16F877 is "used up" by the Ethernet module, there are plenty of PIC I/O opportunities that can still be exploited once the Ethernet module is installed and running. I added a single LED on PORTA to demonstrate basic I/O

Schematic 2. Connections to the Realtek chip.



using Telnet and TCP/IP or a simple VB program and UDP.

The Easy Ethernet Controller's Ethernet module is based on the RTL8019AS Ethernet IC. With the help of the on-module 20 MHz crystal and an integral isolation magnetics/RJ-45 jack assembly, the RTL8019AS does everything necessary to put an Ethernet frame on the LAN including blinking the status LEDS which are also mounted on the Easy Ethernet Controller module.

All we have to do is supply +5 volts to the Ethernet module and interface its address and data bus pins to the PIC16F877, which is running our BootLoader and Internet protocol firmware.

The RTL8019AS contains a set of registers that must get some of their data from an external 9346 EEPROM. As you can see by the schematic, there is no 9346 EEPROM device on the Easy Ethernet Controller. That's because I used a PIC firmware trick to "fake out" the RTL8019AS into believing the PIC16F877 is the 9346.

By employing this technique, I can run the Easy Ethernet Controller at full or half duplex and I can also change the way the status LEDs behave just as if the 9346 were present. EECS, EEDO, EEDI, and EESK are the RTL8019AS's 9346 interface pins. The PIC16F877 firmware supplies and receives Ethernet control sequences and data through the Ethernet module's SD0-SD7 data lines.

SA0-SA4 address the RTL8019AS's internal register stack. When a good Ethernet frame is received, the INT0 pin signals the PIC16F877 that data is available.

The PIC16F877 then uses the IORB and IOWB lines to read data from and write data to the Ethernet module, respectively.

The Ethernet module JP pin is normally tied high to allow the INT0 and "fake" EEPROM functionality to be employed. If JP is left open, it will be pulled low internally by the RTL8019AS and other modes of operation can be explored. In our application, JP is tied high.

Easy Ethernet Controller Software

The Easy Ethernet Controller firmware is too lengthy to include in print here and just as lengthy to describe. So, the source code for the Easy Ethernet Controller is profusely commented to allow you to understand and then modify the code for your use.

The Easy Ethernet Controller firmware consists of modules that perform IP, TCP, UDP, ARP, and PING operations. The PIC16F877 firmware also is responsible for initializing the Ethernet module.

In addition to these duties, the firmware also has room to add an application that controls the PIC16F877's I/O pins.

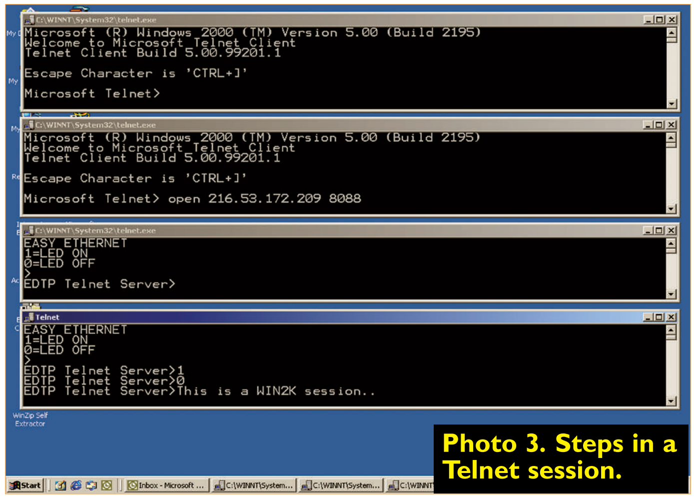


Photo 3. Steps in a Telnet session.

The Easy Ethernet Controller IP address and MAC (hardware) address can be modified inside the Easy Ethernet Controller source code. The default Easy Ethernet Controller IP address is 192.168.1.150 and the default MAC address is 0VOLTS.

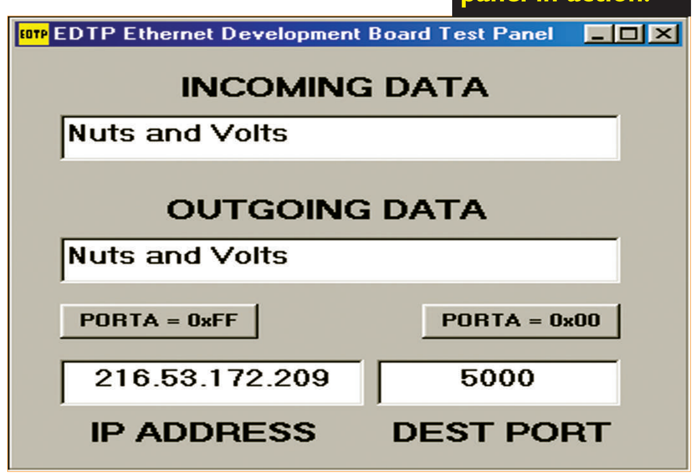
The MAC address is used by the Ethernet mechanism just like the IP address is used by UDP and TCP. The ARP function is used by your PC to figure out what the Easy Ethernet Controller's MAC address is.

Once your PC gets the Easy Ethernet Controller's MAC address from the Easy Ethernet Controller itself via an ARP request/reply sequence, it matches up the Easy Ethernet Controller IP and MAC addresses so it knows from then on how to contact the Easy Ethernet Controller over the LAN.

A Telnet application comes standard with Windows 2000 and Windows 98/ME and can be invoked by simply typing in "telnet" in a DOS window. Photo 2 is a series of screen shots that show you how to use the Win98/ME application to get to the Easy Ethernet Controller.

The topmost Telnet screen is the result of selecting Connect | Remote System. You can use these exact Host Name, Port, and TermType settings to get to my Easy

***Photo 4.* The test panel in action.**



Ethernet Controller, which is alive on the Internet. However, for your home or office network, you will want to set the IP address to match your LAN settings.

Remember, you can change the port address and IP address in the Easy Ethernet Controller firmware. So, be sure what you enter here matches the firmware if you decided to make a change.

The middle Telnet window in Photo 2 appears after clicking the Connect button in the top window. The banner "EASY ETHERNET" is sent from the Easy Ethernet Controller, as well as the LED messages that follow.

The prompt character (>) tells you the Easy Ethernet Controller has been contacted and is ready to go to work manipulating the LED. After hitting the Enter key, the one-character prompt becomes an identifier.

At this point, I entered a "1" to illuminate the LED on the Easy Ethernet Controller board. I didn't have to hit Enter after entering the 1, but for clarity I did so here.

Next, I extinguished the LED by entering "0" followed by the Enter key. Examining the Easy Ethernet Controller source code will reveal that all characters sent to the Easy Ethernet Controller are echoed to the Telnet client.

Only a 1 or 0 will affect the LED. For those of you running Win2K, Photo 3 is the way it will look to you.

TCP/IP is by far the most spoken word when someone talks about the Internet. TCP uses a logical connection to make sure that the data between nodes is not compromised. UDP does no such thing and really doesn't care if the data gets there or not.

The good news is that most of the time the UDP generated data does get where it's going without problems.

The Easy Ethernet Controller takes advantage of this. A UDP application is included inside the Easy Ethernet Controller firmware, and to demonstrate this easy way to communicate, I've written a simple VB program to exercise the Easy Ethernet Controller using your LAN connection or over the Internet.

Like TCP, UDP works with IP addresses and ports. The main difference in the two protocols is that UDP is more like using a serial port while TCP has "rules" that must be followed to send and receive data.

Photo 4 is a shot of the UDP VB program in action. When you type into the OUTGOING DATA window, the UDP utility in the VB program is hardcoded to send the data to the Easy Ethernet Controller's UDP port 7.

The Easy Ethernet Controller

firmware sees this and echoes the data back to the sender and the echoed data is displayed in the INCOMING DATA window.

The Easy Ethernet Controller firmware also has instructions that allow the LED to be toggled. Clicking on the PORTA = 0x00 sends a message to the Easy Ethernet Controller to take the PORT A bit 4 pin low and thus fire up the LED. The PORT A = 0xFF does the opposite function.

The DEST PORT value is the default port address coded into the Easy Ethernet Controller firmware and is used by UDP to talk to the LED bit. Again, the IP ADDRESS is pointing to my Easy Ethernet Controller on the Internet and can be changed to reflect the IP address that is suitable for your purposes on your LAN.

You can test both the UDP and TCP methods of talking to the Easy Ethernet Controller simultaneously as the Easy Ethernet Controller is able to handle a combination of UDP and TCP messages.

Your Turn

I purposely didn't get into the low-level bits and bytes of the Internet protocols because I wanted to prove to you that you don't have to know all of that to use the Internet and its tools for control and monitoring.

For those of you that do want to get down and dirty, there's plenty of bit-level information available from various Internet sites and for the Easy Ethernet Controller specifically, there's plenty of code and Internet-control-related text at **www.edtp.com**

You don't have to have a physical Easy Ethernet Controller to use the Telnet and VB stuff I described here. I'll keep an Easy Ethernet Controller on the net at 216.53.172.209 to allow you to play with the technology using your PC and an Internet connection via your ISP.

To see the Easy Ethernet Controller from a Telnet connection, use a Host Name of 216.53.172.209 with a Port of 8088.

For UDP functions, the IP address is 216.53.172.209 and the port number for echo is 7 decimal while the port number for LED control is 5000 decimal.

You can download the UDP VB program from the EDTP website if you don't want to write your own.

It's really neat to see things happen to the Easy Ethernet Controller knowing that the command was given and transferred via the Internet or a LAN connection.

Obviously, you won't be able to "see" the LED toggle at my end.

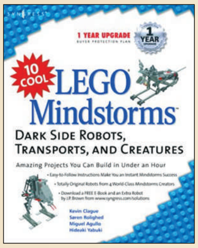
So, build your own Easy Ethernet Controller and experience the thrill. **NV**

Selected Titles for the Electronics Hobbyist and Technician—

The Nuts & Volts Hobbyist Bookstore

Robotics

10 Cool LEGO Mindstorms: Dark Side Robots, Transports, and Creatures
by Kevin Clague / Søren Rolighed / Miguel Agullo / Hideaki Yabuki

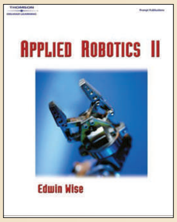


Okay, you bought the kit for yourself or one of your kids. You used the instructions in the box to build a robot or two. Now what? You may not be ready to design and build your own robots, but you don't want to build the same robot over again. This book is the perfect way to build additional projects from the same kit, and then improve and design your own. Ten cool projects — one hour each ... perfect! **$24.95**

Robots, Androids and Animatrons, Second Edition
by John Iovine

In *Robots, Androids, and Animatrons — Second Edition*, you get everything you need to create 12 exciting robotic projects using off-the-shelf products and workshop-built devices, including a complete parts list. Also ideal for anyone interested in electronic and motion control, this cult classic gives you the building blocks you need to go practically anywhere in robotics. **$19.95**

Applied Robotics II
by Edwin Wise



Instructive illustrations, schematics, part numbers, and sources are also provided, making this book a "must" for advanced builders with a keen interest in moving from simple reflexes to autonomous, AI-based robots. Create larger and more useful mobile robots! Ideal for serious hobbyists, *Applied Robotics II* begins by discussing PMDC motor operation and criteria for selecting drive, arm, hand and neck motors **$41.95**

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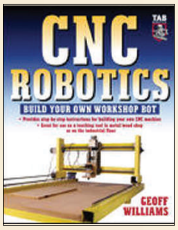
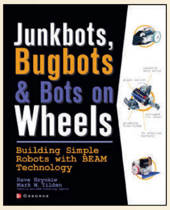
CNC Robotics
by Geoff Williams



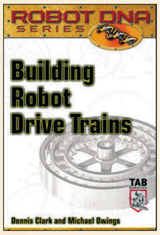
CNC Robotics gives you step-by-step illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot — and that can be customized to suit your purposes exactly, because you designed it. Written by an accomplished workshop bot designer/builder. **$34.95**

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now you can use electronic parts from old Walkmans, spare remote controls, even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo-wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot-building revolution! **$24.99**

Building Robot Drive Trains
by Dennis Clark / Michael Owings



This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

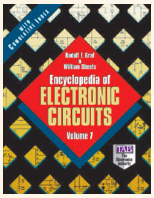
* The Basics of Robot Locomotion
* Motor Types: An Overview
* Using DC Motors
* Using RC Servo Motors
* Using Stepper Motors
* Motor Mounting
* Motor Control
* Electronics Interfacing
* Wheels and Treads
* Locomotion for Multipods
* Glossary of Terms/Tables, Formulas

The Robot Builder's Bonanza
by Gordon McComb

A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

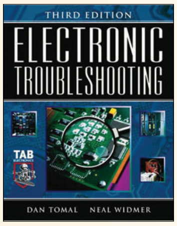
Electronics

Encyclopedia of Electronic Circuits Vol. 7
by Rudy Graf



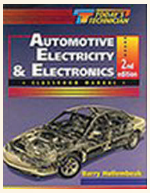
Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits, Volume 7*, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Electronic Troubleshooting
by Daniel Tomal / Neal Widmer



If you work with electronics — either through your profession or your pastime — here's one resource you need handy at all times: the updated, Third Edition of McGraw-Hill's *Electronic Troubleshooting*. Revamped to include the latest electrical and electronic devices and problem-solving methods, this information-packed volume provides a fundamental understanding of electronic troubleshooting theory. **$49.95**

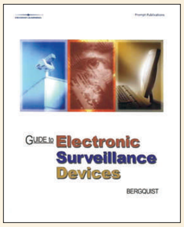
Today's Technician: Automotive Electricity & Electronics
by Barry Hollembeak / Jack Erjavec



The best-selling book/shop manual package in our landmark Today's Technician series, the third edition of *Automotive Electricity and Electronics* continues to equip its readers with the most in-depth discussion of basic theory, safety, tools, and major automotive electrical/electronic systems available anywhere! And, perhaps most importantly, we've added many all-new examples to guide readers, step-by-step, to complete mastery of all of the electrical/electronic knowledge plus hands-on diagnostic and troubleshooting skills they need to become highly skilled automotive technicians. **$75.95**

Guide to Electronic Surveillance Devices

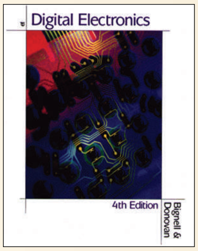
by Carl Bergquist



Enjoy the peace of mind that comes from knowing how to set up and maintain an effective surveillance system! Perfect for do-it-yourselfers, *Electronic Surveillance Devices* contains all of the information needed to enhance the safety and security of a home or office, from safeguarding against theft to monitoring employee performance and preventing illegal activities from occurring on site. **$35.95**

Digital Electronics

by James Bignell / Robert Donovan



This basic text for *Digital Electronics* offers complete, practical coverage of the latest digital principles, techniques, and hardware. Written in a concise, easy-to-read style, it includes everything from basic digital concepts to an introduction to microprocessors/microcontrollers.
$99.95 for subscribers
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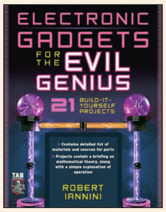
Electronic Gadgets for the Evil Genius

by Robert Iannini

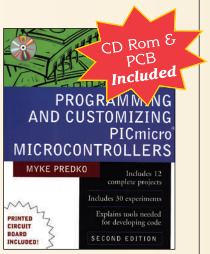


The do-it-yourself hobbyist market, particularly in the area of electronics, is hotter than ever. This books gives the "evil genius" loads of projects to delve into, from an ultrasonic microphone, to a body heat detector, and all the way to a *Star Wars* Light Saber. This book makes creating these devices fun, inexpensive, and easy. **$24.95**

Microcontrollers

Programming & Customizing PICmicro Microcontrollers *2nd Edition*

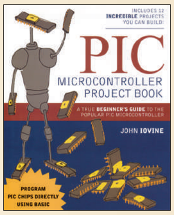
by Myke Predko



This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICMicro's hardware architecture and software schemes complement the host of experiments and projects making this a true, "learn as you go" tutorial. **$49.95**

PIC Microcontroller Project Book

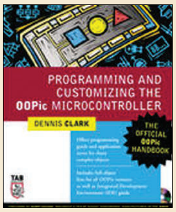
by John Iovine



This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number logger and distinct ring detector and router ... home automation using X-10 communications ... digital oscilloscope ... simulations of fuzzy logic and neural networks ... and many other applications. **$29.95**

Programming and Customizing the OOPic Microcontroller

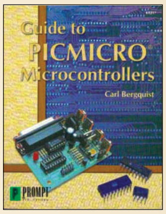
by Dennis Clark



If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — *Programming and Customizing the OOPic Microcontroller*. This is the official OOPic Handbook, fully endorsed by Savage Innovations, the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

Guide to PICMICRO Microcontrollers

by Carl Bergquist



Aimed at both students and seasoned users, this book will take the reader through the peripheral interface controller (PIC) like no other text. Hardware and software are also discussed in detail. Topics include: physical appearance, electrical structure, software requirements, hardware requirements, prototype layout boards, simple PIC programmers, PIC instruction set, use of the Microchip tools including MPLAB and Technical Library, software applications, software codes, and 8-10 PIC projects. **$45.95**

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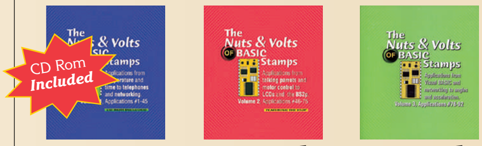

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In 1995, Scott Edwards began authoring a column on BASIC Stamp projects in *Nuts & Volts Magazine*. The column quickly became a favorite of *Nuts & Volts* readers and continues today with Jon Williams at the helm. *The Nuts & Volts of BASIC Stamps* is a three-volume collection of over 90 of these columns.

Volume 3 is new and contains columns 76-92!

High Voltage

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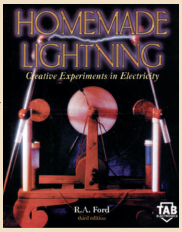
by R.A. Ford



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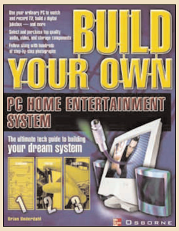

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Electronics as a hobby is not going away as some

The NEW Electronics Experimenter

What do you think of when you hear the term electronic hobbyist or experimenter? A guy in a grungy basement loaded with old discarded equipment and junk boxes, a cluttered work bench with dozens of unfinished projects and the air redolent of rosin smoke from the soldering iron? Or maybe you think more of the classic amateur radio operator in his ham shack with transceivers and a 50 foot tower bristling with obnoxious antennas that offend the neighbors. Or do you picture a personal computer hardware hacker who modifies, upgrades, and interfaces his PC with everything in sight.

I seem to see a person who likes to build electronic circuits and equipment. A bench with breadboarding socket, power supply, multimeter, function generator, oscilloscope, and the usual parts boxes. This person probably even designs some circuits and equi

by Louis Frenzel

Not Your Father's Electronics

Continuing the clichés', we have come a long way, baby. Or, welcome to the 21st century. Whatever. I was going through a huge stack of old electronic hobbyist magazines recently as I was cleaning out my garage. What nostalgia! We used to build lots of simple one, two, or three transistor projects. Many of us built commercial kits. But then a funny thing happened. Integrated circuits came along. The microprocessor was developed then the personal computer. Those three things set the stage for what hobbyists would do in the future. The ICs, microprocessors, and the PC set into motion a whole sequence of events that would change the electronics hobby forever.

The big changes started with integrated circuits. Hobbyists really took to these in the early days because you could do amazing things with 555 timers, 741 op-amps, and 7400 series TTL. But with the introduction of the microprocessor in the mid-1970s, the big changes really started to occur. The demand for larger, faster, better, and cheaper microprocessors and memory stepped up the competition in the semiconductor business. The chip companies learned how to make smaller, faster circuits that allowed you to put much more circuitry on a chip. And the race was on to see who could make the largest chip. The smaller circuit features also made them faster. While all this brought us better microprocessors, memories, and larger faster PCs, it started making electronic hobbying more difficult. We stopped using so much TTL and CMOS logic and started making all our digital projects with an embedded controller. We essentially traded the soldering iron in for a programming language.

With the ability to make thousands, even millions of transistors and circuits on a single chip, the complexity of ICs grew exponentially. High volume kept the prices low and affordable even for hobbyists. But the complexity turned away many who were not professional engineers. The larger chips had different more challenging packaging, as well. Dual inline packages (DIPs) slowly went away in favor of a variety of surface mount and ball grid array packages. Not only did the chips get smaller but it was also far more difficult to experiment with and solder to a PC board. Have you ever worked with a surface mount IC only a few millimeters square? And have you ever tried to solder a 1,000 pin ball grid array (BGA) package to a board? Good luck.

On top of the packaging problem, circuits got faster. Low MHz digital clock rates quickly became hundreds of MHz and today, most of the newer digital ICs easily run at clock speeds of several GHz. Analog circuits, especially radio frequency (RF) circuits, also benefited with wider bandwidths and operating frequencies easily into the low GHz range. While high speeds and frequencies are surely welcomed by experimenters, as well as engineers, hobbyists couldn't afford the test equipment to stimulate and measure the outputs of such circuits. Gigahertz digital sampling scopes cost thousands of dollars. And what you really need in working with RF is a spectrum analyzer. A cheap one will set you back by some dollar value in the low five digits.

So what did we do? Many hobbyists simply followed the lead of the magazines and continued to build projects with decades old parts. Projects still feature the 2N3904 and 2N2222 bipolars of the 1970s while today, virtually all new designs use MOSFETs. Actually, over 90% of all transistors made are MOSFETs, and I'm not just making that up. Furthermore, hobbyists still use the ICs of yesteryear. The still popular 555 timer and 741 op-amp were actually born in the 1970s. Yet these are rarely used in new designs today. Neither is the popular 7400 series TTL digital logic ICs. These and their CMOS offshoots, have been relegated to the hobbyist as well. I know. These parts are still available, cheap, and easy to use. I'm not knocking them; I am just saying that there are many other better ways to do the same thing. Are hobbyists to lazy to learn and use them?

Today, virtually all digital equipment is made with an embedded controller and if that is not fast enough, a programmable logic device (PLD) like a GAL, PAL, or FPGA is used. Many digital circuits are custom designs called applications specific integrated circuits (ASIC, pronounced A sicks). These devices are available to hobbyists but instead, most prefer to keep using the older devices because they are cheap, simple, understandable, and manageable. But they certainly do not represent the latest technology. That is what has turned off many to the hobby — low tech. It's like continuing to try to build a crystal radio set when the real standard is some exotic microwave, DSP-based, software defined radio. That's what a modern cell phone is and most of us have one these days. Somehow crystal sets or even 555 LED flashers, 7-segment LEDs and 7400 counters bore us to death.

Just think of all the high tech stuff we own and take for granted. I mentioned cell phones, but we also own CD players, DVD players, flat panel LCD TV and PC screens, 2 to 3 GHz Pentiums in our laptops, digital cable TV, satellite TV, digital radio, cable modems, MP3 players, DSL lines, and on and on. TTL projects and CB radio aren't even on our radar screens anymore. Young people today simply take all super high tech stuff for granted. There is no thought of trying to build, much less design anything like these common devices. A quick look inside any modern electronic product today scares us to death. Lots of ICs plus a scattering of tiny surface mount discretes, all packaged into some super tiny housing on a multilayer PC board. No wonder hobbyists are giving up on building.

Another factor is our on-going need for instant gratification. Our attention span gets shorter thanks to TV, video games, PCs, and the

Internet, and we all seem to want everything right now. No one wants to wait even a few microseconds any more. That is one of the factors that killed the kit business — one of the major sectors of the electronic hobbyist market. I worked for Heathkit for many years and saw that business gradually fade away in the 1980s and 1990s. People loved to build their own electronic equipment. It gave them personal satisfaction and they learned something along the way. But, the kits kept getting more complex and more expensive. It became cheaper to buy a wired and tested product as ICs got larger. Manufacturing methods improved, costs dropped, and competition from Asia killed most US electronic companies. And no one wanted to spend hours or even days or weeks building a kit when they could run over to the electronics store and buy one to use *right now.*

Another thing electronics hobbyists used to do is fix things. They repaired TV sets and stereos, radios, small appliances, and other things. Today, we do not repair electronics equipment. If it goes bad, we throw it away and get a new and better one for less money. Even if you could find someone to do the repair, what you would end up with is an old product that costs more to fix than it costs to buy a new one with the latest bells and whistles. Technology has done that for us. It actually costs more to have something repaired because of the very high labor expense. And even if you do want to repair things, you must pay big bucks for the esoteric test equipment needed to make the tests. Electronic repair is not an economically viable thing any more. Just buy new and better stuff for less money and enjoy.

So electronics as a hobby has really changed. Oh yes, you can still build crystal sets, 555 timer circuits, and TTL projects, but few are doing that any more. Technology has moved on. A few electronics hobbyists like I just described are still around but are fading fast. And a new type of hobbyist has emerged. Few have recognized this *new* electronics experimenter.

Electronics as a hobby hasn't gone away. If I had to classify it, I would say that it is not necessarily better or worse, it is just different.

The *New* Electronics Hobbyists

There are just as many if not more people interested in electronics today as ever before. But they don't make one tube radios or TTL digital dice. Most of them don't work at the component level. They think systems instead of circuits. They buy and use equipment. They interconnect the equipment, find new uses, and regularly modify or enhance it. For example, as amateur radio equipment got more complex, fewer and fewer hams did the home brew thing. They stopped building the receivers and transmitters and bought commercial transceivers. They became "appliance operators." They purchased and used commercial equipment but still built small manageable projects. Well that is how most electronics hobbyists do it today. Yes, the hobbyists are still out there, but they are just working at a different level.

Here is a summary of the *new* electronics hobbyists and experimenters today and what they do.

Audio

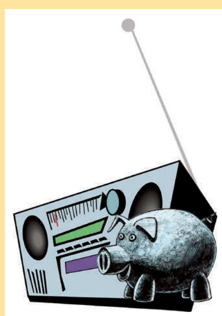
Audio is a huge hobby. Most people like music and electronics is the key to enjoying it. Hobbyists buy stereo systems mainly to listen to music and play around with speakers. A great deal of the audio hobbying is in digital music, downloading music from the Internet, burning your own CDs, creating files for your MP3 player, and so on. Electronic music is big with lots of folks owning electronic synthesizer keyboards, as well as the hardware and software for recording and manipulating music with a computer.

Shortwave Listening

There is still a good number of people that do this. Mostly they buy commercial receivers to listen to shortwave and broadcast bands or buy scanners to listen to local police, fire, etc. They experiment with antennas mostly but rarely build anything.

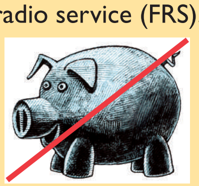
Ham Radio

Still one of the biggest electronic hobbies. Mostly hams buy their equipment and experiment with antennas and high power amplifiers. Many also build small projects that are designed to enhance or supplement commercial equipment. Lots of hams experiment with satellites, TV, microwaves, and the new digital transmission modes. There are some opportunities for circuit building but most hams still opt for commercial gear and work at the system level. The biggest exception are the QRP (low power) enthusiasts who do build receivers and transmitters because of their low cost and simplicity. Much of the hobby is in talking with others over the air.



Personal Radio

Those who are not hams but are interested in communications participate in citizens band radio or use the new family radio service (FRS). Again, commercial equipment dominates but there is experimentation with antennas, especially the CB type. CB operators also emulate their ham counterparts by seeking long distance communications with others.



Radio-Controlled Models

Another radio hobby. Again, most of the equipment is commercial but most of it requires manual labor on the mechanical front to mount it. A great deal of effort goes into building the model whether it is a plane, boat, or car.

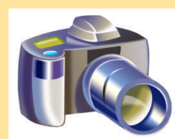
Robotics

This is one of the hottest and growing segments of the hobby field. And because there are few commercial robot manufacturers serving this sector, most hobbyists build their own. A great deal of it is mechanical and the electronics is relatively simple. Motors and control circuits, embedded controllers, sensors and the like are still manageable by a hobbyist. The BattleBots of TV fame have created a hot new way to do electronics as a hobby.

Personal Computers

PCs have become appliances just like almost anything else. Yet you can customize them to your needs such as music, gaming, video editing, home networking, or just programming. Adding peripherals and add-in cards is where all the action is. Data acquisition, virtual instruments, video and still photography, and home control are major applications. The emphasis is still on the software, and learning to program in C or Visual BASIC is an excellent path for the experimenter.

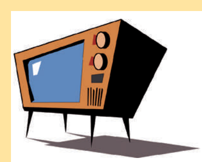
Video and Cameras



This is a smaller segment but many like to play with camcorders and digital cameras. It is strictly an appliance hobby, but a creative one with definite system level action.

TV

Another appliance hobby and an expensive one. But there is lots to play with. Cable TV, satellite TV, high definition TV, flat screens, VCRs, DVD players and recorders, and personal video recorders (TiVo, etc.). A hobby that the whole family will benefit from.



The Gadgeteer

Have you ever seen so many electronic gadgets? There seems to be a fringe faction that loves these things. Perhaps these gadgets can serve as the introduction to a more involved electronics hobby effort. Just look at how many toys have electronics: animated dolls and animals, educational items, remote controlled cars and boats, and of course, the many games. Then there are the things like GPS receivers for navigation, wireless temperature sensors and weather stations, and electronic clocks and watches, and portable DVD and CD players. All of these gadgets have one thing in common: they contain an embedded controller that literally does everything. Most of these chips sell for less than $1.00. Once you learn to work with these devices, you can just about make anything electronic you want. It's a good place to start learning and enjoying the hobby.

Experimenting and Learning

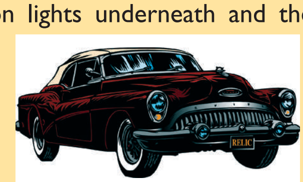
There is a segment of the hobby that still likes to build projects from scratch or from kits. There are still a few kit companies out there but most of the kits are pretty simple. No more Heathkit TV sets, hi-fi's, or computers. And many still like to build simple projects with a few ICs or transistors. There is still a great fascination with crystal sets, believe it or not. There is major gratification associated with designing and/or building something yourself. I believe that a significant part of this segment of the hobby is self learning. A major part of all hobbies is learning more about the subject and becoming competent with it. Nothing beats hands-on experimentation for learning.

Home Networking and Control

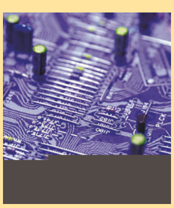
People love to enhance their homes. I have seen many people start electronics as a hobby by adding useful and interesting electronic gadgets. Security systems are a good example of an electronic system-level hobby project. Then there are the remote control applications for ceiling fans, drapes, and lights. Home networking is getting bigger as more homes have two or more PCs. A wireless or wired network lets multiple computers share a high speed broadband Internet connection by DSL or cable modem, as well as a printer. This is one of the fastest growing hobby areas.

Autosound

Looking at the magazine stand recently I saw several magazines devoted to sound systems for cars and trucks. Any time you have several magazines addressing some segment, you can be sure there are many enthusiasts. The autosound field is enormous. Lots of folks love to install killer sound systems in their cars and trucks. From 400 Watt amps and woofers to the 400 disc CD players, these systems are "cool." I just love it when I see a pickup with neon lights underneath and the doors pulsating in and out with the speakers. Add to this the new Sirius and XM satellite radios and you have lots of projects to work on. Save up ...



Microcontrollers



Modern electronics experimenters build projects from scratch using embedded controllers. These cheap, single chip computers can be programmed to do almost anything. Most of the work is in the programming. However, considerable effort must also go into building the interfaces and I/O to implement the application. This is one of the most fun and creative parts of electronics experimentation today. A huge part of this sector is programming. This may be the core of electronics experimentation today as there is just about nothing you can't make with an embedded controller. **NV**

Some Interesting Info ...

*I have been reading electronics hobbyist magazines for more years than I care to admit. As a kid, I was reading **Popular Electronics**, **Radio Electronics** and **Electronics World**. I also read the ham radio magazines like **QST, CQ** and **73.** In the late 1970s and 1980s, a whole slew of computer hobbyist magazines came along including **Byte, Creative Computing, Kilobyte, Interface Age,** and others. Electronics as a hobby probably peaked in the 70s and 80s. All the emphasis shifted to PCs.*

*Then the electronics magazines started going away one by one. Magazines like **Hands-On Electronics**, **Elementary Electronics**, and **Modern Electronics** silently disappeared. Then magazines merged and changed ownership. **Popular Electronics** was one of those that survived, for a while. **Radio Electronics** finally went away and **Electronics Now** came along and it too was phased out. Finally, in a last ditch effort to survive, Gernsback magazines came up with **Poptronics**. It went away in December, 2002. The only remaining purely electronics hobbyist magazine now is **Nuts & Volts**. The ham magazines like **QST** and **CQ** are still going strong, but Wayne Green's long running **73** magazine just recently closed the doors. I also read **Popular Communications** and **Circuit Cellar**. The latter is more of a professional engineering magazine focusing on embedded controllers, but their projects are great for hobbyists. It has kept up with the times.*

Magazines go away for two main reasons: they lose readers and/or advertisers. In the first case, readers lose interest if you don't cover what they want. And second, if you lose the readers, the advertisers have little reason to buy ads. Basically what happened is that the magazines did not keep up with the technology. As it changed and got more esoteric, they avoided a great deal of the new stuff and kept producing material they had been successful with in the past. The readers didn't buy it. As the old saying goes, "If you keep doing the same old thing, you will get the same old result." That is clearly what happened here.

Another thing also happened. The magazines got more focused. There are magazines for audio, autosound, shortwave listening, electronic music, PCs, ham radio, and so on. And most of these magazines are at the systems level and not the circuit level.

*Is there still an electronics hobbyist/experimenter market? You bet. But it is significantly different from what it used to be. Thank goodness that **Nuts & Volts** has had the vision to keep up with the technology and change directions as the market changes — not to mention spinning off a robotics magazine, too.*

by D. Prabakaran

IGDG — Internet Based Global Differential GPS

IGDG — Internet based global differential GPS — is by far the most accurate real-time global positioning system. This patented state-space global differential system using real time data from NASA's Global GPS Network (GGN) provides corrections to the GPS orbits and clocks that are globally uniform and seamless. Users anywhere on the ground, in the air, or in near space can have access to the world's most precise differential corrections. It uses the open Internet to collect real time GPS data from NASA's GGN sites, and to disseminate the differential corrections to authorized users. IGDG has demonstrated 10 cm horizontal positioning accuracy, and 20 cm vertical positioning accuracy.

IGDG is geared toward users carrying dual-frequency receivers. These high-end users typically require high-accuracy positioning. Having eliminated the ionosphere as an error source using dual-band receivers, these users are still susceptible to errors in the GPS ephemeredes and clocks. Ground-based users and aircraft must also deal with errors due to the troposphere. Accurate correction for the GPS ephemeris and clock errors requires a network of GPS reference sites. With JPL's patented Global Differential GPS (GDGPS) architecture, a well-distributed global network of about a dozen sites is sufficient for continuously providing GPS ephemeris and clock corrections for GPS satellites.

IGDG have taken advantage of the NASA Global GPS Network (GGN), which is operated and maintained by JPL. The GGN consists of approximately 60 sites, which have traditionally been operated in batch mode. A subset of the GGN is equipped with computers and Internet connection. IGDG has been designed to return GPS data in real time from remote receivers. IGDG collects, edits, and compresses the raw GPS observables at the remote site. It then transmits the packetized data over the open Internet to the processing center. At the processing center, the global data is analyzed by IGDG to produce precise GPS orbits and clocks. These are formatted as

corrections to the GPS broadcast ephemerides, encoded, and are provided over the Internet to authorized users.

WAAS

WAAS stands for Wide Area Augmentation System. It's a system of satellites and ground stations that provide GPS signal corrections, giving you even better position accuracy, an average of up to five times better accuracy. A WAAS-capable receiver can give a position accuracy of better than three meters, 95 percent of the time. WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing, and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite.

WAAS consists of approximately 25 ground reference stations positioned across the US that monitor GPS satellite data. Two master stations, located on either coast, collect data from the reference stations and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through one of two geostationary satellites, or satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal.

Currently, WAAS satellite coverage is only available in North America. There are no ground reference stations in South America, so even though GPS users there can receive WAAS, the signal has not been corrected and thus would not improve the accuracy of their unit. For some users in the US, the position of the satellites over the equator makes it difficult to receive the signals when trees or mountains obstruct the view of the horizon. WAAS signal reception is ideal for open land and marine applications. WAAS provides extended coverage both inland and offshore compared to the land-based DGPS (differential GPS) system. Another benefit of WAAS is that it does not require additional receiving equipment, while DGPS does.

Other governments are developing similar satellite-based differential systems. In Asia, it's the Japanese Multi-Functional Satellite Augmentation System (MSAS), while Europe has the Euro Geostationary Navigation Overlay Service (EGNOS). Eventually, GPS users around the world will have access to precise position data using these and other compatible systems.

GPS Applications

GPS has a variety of applications on land, at sea, and in the air. Basically, GPS is usable everywhere except where it's impossible to receive the signal such as inside most buildings, in caves and other subterranean locations, and underwater. The most common airborne applications are for navigation by general aviation and commercial aircraft. At sea, GPS is also typically used for navigation by recreational boaters, commercial fishermen, and professional mariners. Land-based applications are more diverse. The scientific community uses GPS for its precision timing capability and position information.

Surveyors use GPS for an increasing portion of their work. GPS offers cost savings by drastically reducing set-up time at the survey site and providing incredible accuracy. Basic survey units, costing thousands of dollars, can offer accuracies down to one meter. More expensive systems are available that can provide accuracies to within a centimeter.

Recreational uses of GPS are almost as varied as the number of recreational sports available. GPS is popular among hikers, hunters, snowmobilers, mountain bikers, and cross-country skiers, just to name a few. Anyone who needs to keep track of where he or she is, to find his or her way to a specified location, or know what direction and how fast he or she is going can utilize the benefits of the global positioning system.

GPS is now commonplace in automobiles, as well. Some basic systems are in place and provide emergency roadside assistance at the push of a button (by transmitting your current position to a dispatch center). More sophisticated systems show your position on a street map. Currently these systems allow a driver to keep track of where he or she is, and suggest the best route to follow to reach a designated location.

GPS has become important for nearly all military operations and weapons systems. In addition, it is used on satellites to obtain highly accurate orbit data and to control spacecraft orientation. Although the GPS satellite constellation was completed only recently, it has already proved to be a most valuable aid to US military forces. Picture the desert, with its wide, featureless expanses of sand. The terrain looks much the same for miles. Without a reliable navigation system, US forces could not have performed the maneuvers of Operation Desert Storm. With GPS, the soldiers were able to go places and maneuver in sandstorms or at night when even the troops who lived there couldn't. Initially, more than 1,000 portable commercial receivers were purchased for their use. The demand was so great that, before the end of the conflict, more than

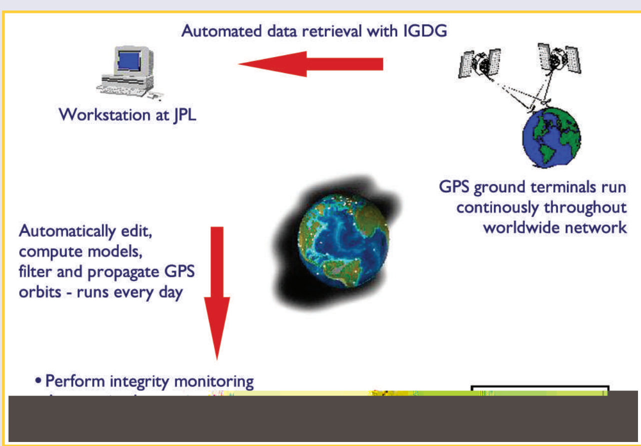


Figure 1. Internet based global differential GPS.

9,000 commercial receivers were in use in the Gulf region. They were carried by foot soldiers and attached to vehicles, helicopters, and aircraft instrument panels. GPS receivers were used in several aircraft, including F-16 fighters, KC-135 aerial refuelers, and B-2 bombers; Navy ships used them for rendezvous, minesweeping, and aircraft operations.

Surveying with GPS: Probably even more important to the surveyor or engineer than the theory behind GPS, are the practicalities of the effective use of GPS.

GPS has numerous advantages over traditional surveying methods:

1. Intervisibility between points is not required.
2. Can be used at any time of the day or night and in any weather.
3. Produces results with very high geodetic accuracy.
4. More work can be accomplished in less time with fewer people.

In order to operate with GPS it is important that the GPS antenna has a clear view to at least four satellites. Sometimes the satellite signals can be blocked by tall buildings, trees, etc. Hence, GPS cannot be used indoors. It is also difficult to use GPS in town centers or woodland. Due to this limitation, it may prove more cost-effective in some survey applications to use an optical total station or to combine use of such an instrument with GPS.

GPS Applications in Agriculture: More and more producers today are using precision farming techniques that can help increase profits and protect the environment. Precision or site-specific farming involves applying fertilizer, pesticides, and other inputs only where they are needed. GPS-guided equipment is often used for variable rate application of fertilizer (based on soil tests) or pesticides (based on pest survey). GPS can also be used to develop the initial reference maps upon which variable rate applications are based. A GPS system on a combine with a yield monitor can be used to develop an on-the-go yield map or can be used to map weed locations from the combine when harvesting. Mounted in an airplane, GPS can be used to guide aerial spraying operations. This reduces production costs, as well as environmental damage from runoff of excess nutrients and pesticides.

GPS can be used to locate weed, insect, or disease infestations and monitor their spread. It can also be used to navigate back to previously mapped infestations to apply controls. A field map can be created using GPS to record the coordinates of field borders, fence lines, canals, pipelines, and point locations such as wells, buildings, and landscape features. The resulting field map might be the first layer a producer would develop for an on-farm GIS (Geographic Information System). Additional layers showing crop damage from hail or drought, and riparian areas or wetlands could be mapped using GPS. Ranchers could use GPS to develop rangeland utilization maps and to navigate back to previously mapped areas or monitoring sites.

GPS Navigation on Land, Sea, and Air: GPS is being used for emergency response (fire, ambulance, police), search and rescue, fleet management (trucking, delivery vehicles, and public transportation), and for automobile guidance systems. Recreational uses of GPS include navigation while hiking, hunting, or skiing. GPS is even used on golf courses to track golf carts, and to let players know how far it is to the center of the greens. GPS is being used for recreational sailing and fishing, and for commercial shipping fleet management. Assisted steering, risk assessment, and hazard warning systems for marine navigation are being developed using GPS. In the air, GPS is being used for en-route navigation (helicopter, airplane, hot-air balloon), aircraft landing, and air-collision avoidance systems.

GPS Mapping: GPS applications in natural resource management include inventory and mapping of soils, vegetation types, threatened and endangered species, lake and stream boundaries, and wildlife habitat. GPS has been used to aid in damage assessment after natural disasters such as fires, floods, and earthquakes. GPS has also been used to map archaeological sites and for infrastructure (streets, highways, and utilities) mapping, management, and planning for future growth.

GPS Receivers

GPS receivers can be hand-carried or installed on aircraft, ships, tanks, submarines, cars, and trucks. These receivers detect, decode, and

process GPS satellite signals. More than 100 different receiver models are already in use. The typical handheld receiver is about the size of a cellular telephone, and the newer models are even smaller. The handheld units distributed to US armed forces personnel during the Persian Gulf War weighed only 50 grams.

The core of GPS receivers comes in two major variations: sequential single-channel and parallel multi-channel. Single-channel GPS units have only one radio receiver unit, and they must step sequentially through all possible satellites. This takes time and degrades their accuracy, since they may lose a "lock" each time they switch channels. Parallel units have from between 4 and 12 receivers, each dedicated to one particular satellite signal, so strong locks can be maintained on all the satellites. There are some two-channel units out there, but in practice these are only slightly better than single-channel units.

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. GARMIN's 12 parallel channel receivers are quick to lock onto satellites when first turned on and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. GARMIN GPS receivers are accurate to within 15 meters on average. Newer GARMIN GPS receivers with WAAS capability can improve accuracy to less than three meters on average.

The most essential function of a GPS receiver is to pick up the transmissions of at least four satellites and combine the information in those transmissions with information in an electronic almanac, all in order to figure out the receiver's position on Earth. Once the receiver makes this calculation, it can tell you the latitude, longitude, and altitude (or some similar measurement) of its current position. To make the navigation more user-friendly, most receivers plug this raw data into map files stored in memory.

Figure 2. GARMIN GPS receiver.

We can use maps stored in the receiver's memory, connect the receiver to a computer that can hold more detailed maps in its memory, or simply buy a detailed map of any area and find the way we need using the receiver's latitude and longitude readouts. Some receivers let us download detailed maps into memory or supply detailed maps with plug-in map cartridges.

A standard GPS receiver will not only place us on a map at any particular location, but will also trace a path across a map as we move. If we leave our receiver on, it can stay in constant communication with GPS satellites to see how location is changing. With this information and its built-in clock, the receiver can give several pieces of valuable information:

- **Odometer** — distance you have traveled
- How long you've been traveling.
- **Speedometer** — current speed of your vehicle.
- Average speed of your vehicle.
- A "bread crumb" trail showing your exactly where you have traveled on the map.
- The estimated time of arrival at the destination if you maintain your current speed.

To obtain this last piece of information, we would have to have given the receiver the coordinates of destination, which brings us to another GPS receiver capability: inputting location data.

Most receivers have a certain amount of memory available for storing navigation data. This greatly expands the functionality of the receiver, because it essentially makes a record of specific points on Earth. The basic unit of user input is the waypoint. A waypoint is simply the coordinates for a particular location. You can save this in the receiver's memo-

Just So You Know ...

Reader Wayne Lauritzen wished to expand on the PRN encoding used in GPS, so he submitted the following. Thanks, Wayne! — Editor Dan

For the C/A code, the Gold codes are a set of 32 orthogonal sequences of ones and zeros, each of which has a length of 1023 elements, or chips. The chip rate is 1.023 Mbps, so the code repeats every millisecond. The codes are easily generated by tapped feedback shift registers. In the actual application, the zeros are replaced by negative ones. These sequences are used as the pseudorandom codes which are assigned to the indivdual GPS satellites. The satellites are often refered to by their PRN number, where PRN stands for Pseudo-Random-Noise. In addition to modulating its ranging message onto the carrier, each satellite modulates its unique PRN onto the L1 carrier wave with binary biphase modulation (BPSK). Effectively, this means that the L1 carrier wave, first modulated by the ranging message, is next multiplied by the PRN. Each time the PRN changes state, the signal gets a 180 degree phase shift. This modulation significantly widens the spectrum, hence the "spread spectrum" terminology. The spread spectrum is very resistant to jamming and, in its uncorrelated state, looks like low power noise. The GPS receiver generates its own local PRN sequence for each of the satellites which it expects to see, and cross correlates that generated Gold code with the received signal. Since the sequences are orthogonal, a good correlation will be found only for the satellite which generated exactly the same code. The correlation effectively extracts a signal from each satellite which can be further demodulated to produce the ranging message.

The Gold codes were named for their discoverer, Robert Gold. Refer to his paper "Optimal Binary Sequences for Spread Spectrum Multiplexing" in *IEEE Transactions on Info Theory*, Oct 1967, pages 619-621, for more information.

ry in two ways:

- You can tell the receiver to record its coordinates when you are at that location.
- You can find the location on a map (the internal map or another one) and enter its coordinates as a waypoint.

This capability lets you use the GPS receiver in a number of different ways. You can record any specific location that interests so that you can find it again at a later time.

You can also combine a series of different waypoints to form a route. One way to use this function is to periodically record waypoints as you travel so that you can backtrack, or follow the same route again in the future. Route-mapping lets you examine a map at home and record a series of waypoints along the roads or trails that lead to your destination.

If the receiver has a data port, you can download routes to a computer, and then upload them again when you plan to follow those routes. Computers can do a lot more with GPS location data than average receivers, because computers have much more memory and much faster processing capabilities. You can also update computer maps easily, so you can include any surveying adjustments or changes in an area.

At its heart, a GPS receiver is just an accurate way to get raw positional data, which can then be applied to geographic information that has been accumulated over the years. This idea is incredibly simple, but it has seemingly endless applications. The considerable contributions of GPS to aviation, maritime navigation, military operation, surveying, and recreation have secured its place among the most revolutionary inventions of all time.

Some GPS receivers have the ability to store attribute information in addition to position information. Examples of attribute information are the condition of a street sign, the name of a road, or the condition of a fire hydrant. Position and attribute information can be stored in a Geographic Information System (GIS) to help users manage their assets more efficiently.

GPS signals work in the microwave band. They can pass through glass, but are absorbed by water molecules (wood, heavy foliage) and reflect off concrete, steel, and rock. This means that GPS units have trouble operating in rain forests, urban jungles, deep canyons, inside automobiles and boats, and in heavy snowfall — among other things. These environmental obstacles degrade positional accuracy or make it impossible to get a fix on our location.

Before Purchasing a GPS Receiver

Before investing in GPS equipment, it is important to clearly define your needs in terms of accuracy level required and end results expected. Identifying your requirements ahead of time will help you determine which type of receiver to purchase, and specific features you will need in order to accomplish your objectives. It will help you avoid purchasing a receiver that you will be disappointed with later because it can't perform the way you expect it to.

Low-end consumer GPS units (from Garmin and Eagle/Lowrance) are in the $100.00 to $200.00 range. All these units have parallel 12-channel receivers.

The greatest thing about Garmin units is that they have a bi-directional serial port that allows them to hook up to your computer. Though many GPS units can only transmit their current positional information, the Garmin units also allow you to transfer their waypoint databases, route tables, and other useful information.

The wide availability of programs supporting the Garmin transfer protocol makes these units good choices for computer-based use.

Consider these issues when selecting a GPS unit:

Battery Life — If you are going to be using the unit away from an auxiliary power source, consider the weight of carrying extra batteries. Units with color displays tend to have a decreased battery life compared to grayscale displays, requiring more frequent battery changes.

Size and Weight — Small lightweight handhelds, large display chartplotters, and panel mounted aviation models.

Antenna Configuration — If you are going to use the unit mainly in the open and in a car, you need a unit with a built-in antenna and the capacity to attach an external antenna, a fixed-mount unit with a mountable external antenna, or an aviation antenna.

DGPS Capability — Do you need the best accuracy possible? If so, combining a Differential GPS receiver with your GPS unit will give you the best accuracy possible. All Garmin GPS units are DGPS-ready and some fixed-mount marine units even have the DGPS receiver built in.

If you're shopping for a unit, pay attention to features like form factor (handheld versus mounted), external antennas, mapping, and computer-controllability. A good strategy is to clearly outline your project requirements and then contact several GPS equipment manufacturers with your specifications. As you research available equipment and ask questions, you will gain an understanding of what kinds of equipment are currently available and will meet your needs. **NV**

Figure 3. Etrex GPS receiver.

BIPOLAR TRANSISTOR COOKBOOK — PART 7

Ray Marston describes a variety of practical transistor audio power amplifier and 'accessory' circuits in this month's penultimate installment of an eight-part series.

by Ray Marston

One of the most popular applications of transistors is in audio power amplifiers. This month we describe the operating principles of various circuits of this type and present a selection of practical audio power amplifier circuit designs. The installment concludes by presenting a practical 'scratch and rumble' filter circuit, which can be used to eliminate these unwanted sounds when playing old-fashioned records/discs through any type of audio power amplifier system.

POWER AMPLIFIER BASICS

A transistor power amplifier's job is that of converting a medium-level medium-impedance AC input signal into a high-level low-impedance state suitable for driving a low-impedance external load. This action can be achieved by operating the transistor(s) in either of two basic modes, known as 'class-A' or 'class-B.'

Figure 1(a) shows a basic class-A audio amplifier circuit; Q1 is a common-emitter amplifier with a loudspeaker collector load, and is so biased that its collector current has a quiescent value halfway between the desired maximum and minimum swings of output current, as shown in Figure 1(b), so that maximal low-distortion output signal swings can be obtained. The circuit consumes a high quiescent current, and is relatively inefficient; 'efficiency' is the ratio of AC power feeding into the load, compared with the DC power consumed by the circuit, and at maximum output power is typically about 40%, falling to 4% at one tenth of maximum output, etc.

Figure 2 shows an example of a low-power (up to a few dozen milliwatts) high-gain general-purpose class-A amplifier that draws a quiescent current of about 20 mA and is suitable for driving a medium impedance (greater than 65Ω) loudspeaker or headset. Q1 and Q2 are wired as direct-coupled common-emitter amplifiers, and give an overall voltage gain of about 80 dB. Q1's base bias is derived (via R2) from Q2's emitter, which is decoupled via C3 and thus 'follows' the mean collector voltage of Q1. The bias is thus stabilized by DC negative feedback. Input pot RV1 acts as the circuit's volume control.

A basic class-B amplifier consists of a pair of transistors, driven in anti-phase but driving a common output load, as shown in Figure 3(a). In this particular design, Q1 and Q2 are wired in the common-emitter mode and drive the loudspeaker via push-pull transformer T2, and the anti-phase input drive is obtained via phase-splitting

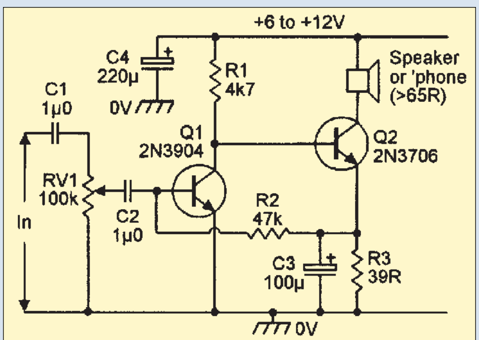


Figure 2. General-purpose high-gain low-power audio amplifier.

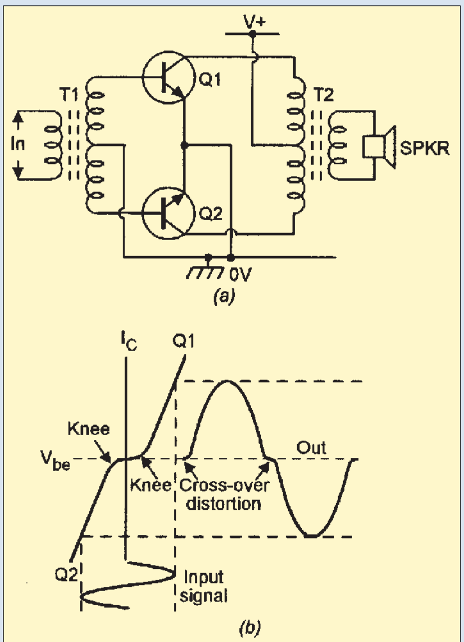


Figure 3. Basic circuit (a) and transfer characteristics (b) of a class-B amplifier.

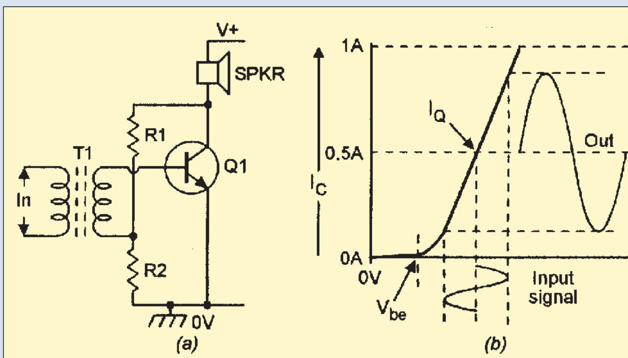


Figure 1. Basic circuit (a) and transfer characteristics (b) of a class-A amplifier.

transformer T1. The essential features of this type of amplifier are that both transistors are cut off under quiescent conditions, that neither transistor conducts until its input drive signal exceeds its base-emitter 'knee' voltage, and that one transistor is driven on when the other is driven off, and vice versa. The circuit consumes near-zero quiescent current, and has high efficiency (up to 78.5%) under all operating conditions, but it generates severe cross-over distortion in the amplifier's output signal, as shown in Figure 3(b). The basic class-B circuit must thus be modified if it is to be used as a practical audio power amplifier; the modified circuit is known as a 'class-AB' amplifier.

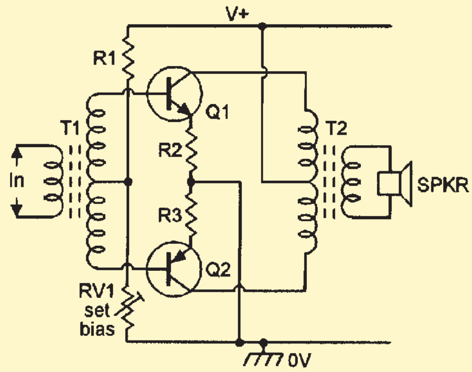


Figure 4. Basic circuit of a class-AB amplifier.

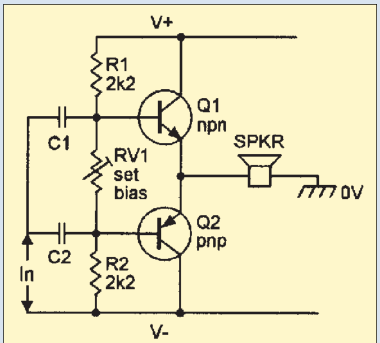


Figure 5. Basic class-AB amplifier with complementary emitter follower output and dual power supply.

CLASS-AB BASICS

The cross-over distortion of the class-B amplifier can be eliminated by applying slight forward bias to the base of each transistor, as shown in Figure 4, so that each transistor passes a modest quiescent current. Such a circuit is known as a class-AB amplifier. Circuits of this type were widely used in early transistor power amplifier systems but are now virtually obsolete, since they require the use of transformers for input phase-splitting and output loudspeaker driving, and must have closely matched transistor characteristics if a good low-distortion performance is to be obtained.

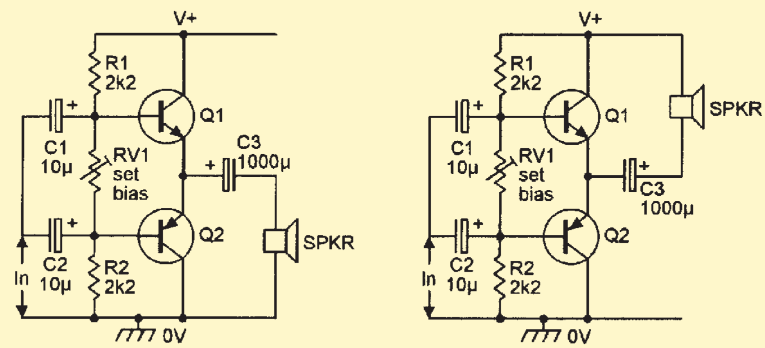


Figure 6. Alternative versions of the class-AB amplifier with a single-ended power supply.

Figure 5 shows the basic circuit of a class-AB amplifier that suffers from none of the snags mentioned above. It is a complementary emitter follower, and is shown using a split (dual) power supply. Q1 and Q2 are biased (via R1-RV1-R2) so that their outputs are at zero volts and zero current flows in the loudspeaker load under quiescent conditions, but have slight forward bias applied (via RV1), so that they pass modest quiescent currents and thus do not suffer from cross-over distortion problems. Identical input signals are applied (via C1 and C2) to the bases of both emitter followers. This circuit's operation was described in Part 2 of this 'Cookbook' series.

The basic Figure 5 circuit does not require the use of transistors with closely matched electrical characteristics, and gives direct drive to the speaker. It can be modified for use with a single-ended power supply by simply connecting one end of the speaker to either the zero or the positive supply rail, and connecting the other end to the amplifier output via a high-value blocking capacitor, as shown in Figure 6.

The basic Figure 5 and 6 circuits form the basis of virtually all modern audio power amplifier designs, including those in IC form. Many modifications and variations can be made to the basic circuit.

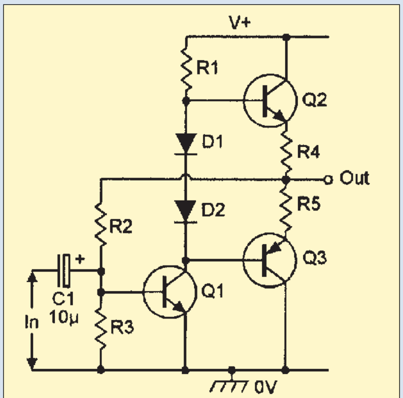


Figure 7. Complementary amplifier with driver and auto-bias.

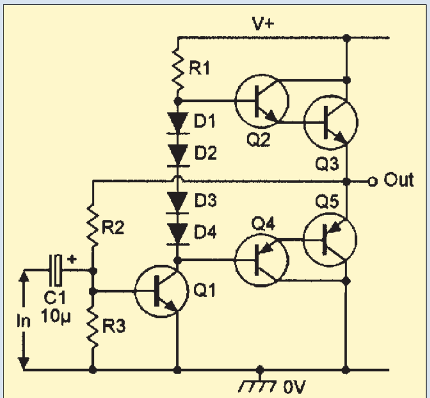


Figure 8. Amplifier with Darlington output stages.

CIRCUIT VARIATIONS

The Figure 5 circuit gives unity overall voltage gain, so an obvious circuit modification is to provide it with a voltage-amplifying driver stage, as in Figure 7. Here, common emitter amplifier Q1 drives the Q2-Q3 complementary emitter followers via collector load resistor R1 and auto-biasing silicon diodes D1 and D2 (the function of these diodes was explained in Part 2 of

this series). Q1's base bias is derived from the circuit's output via R2-R3, thus providing DC feedback to stabilize the circuit's operating points, and AC feedback to minimize signal distortion. In practice, a pre-set pot is usually wired in series with D1-D2, to enable the Q2-Q3 bias to be trimmed; low-value resistors R4 and R5 are wired in series with Q2 and Q3 emitters to prevent thermal runaway, etc.

The input impedance of the basic Figure 5 circuit equals the product of the loudspeaker load impedance and the hfe of Q1 or Q2. An obvious circuit improvement is to replace the individual Q1 and Q2 transistors with high-gain pairs of transistors, to increase the circuit's input impedance, and enable it to be used with a driver with a high-value collector load. Figures 8 to 10 show three alternative ways of modifying the Figure 7 circuit in this way.

In Figure 8, Q2-Q3 are wired as a Darlington NPN pair, and Q3-Q4 as a Darlington PNP pair; note that four base-emitter junctions exist between Q2 base and Q4 base, so this output circuit must be biased via a chain of four silicon diodes.

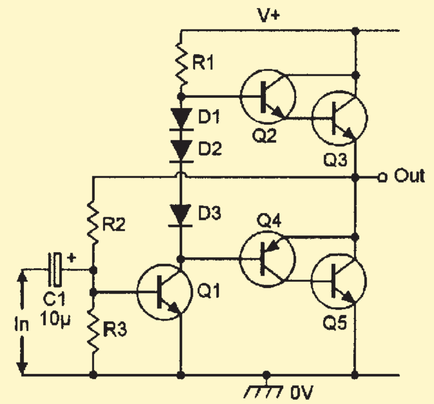


Figure 9. Amplifier with quasi-complementary output stages.

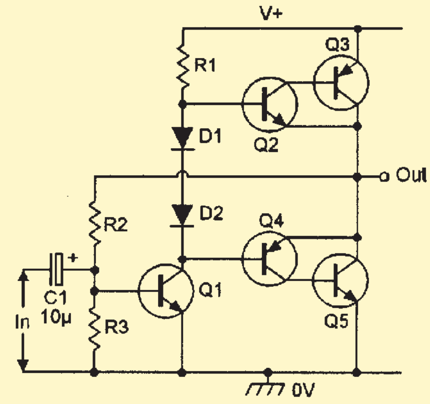


Figure 10. Amplifier with complementary output stages.

In Figure 9, Q2-Q3 are wired as a Darlington NPN pair, but Q3-Q4 are wired as a complementary pair of common-emitter amplifiers that operate with 100% negative feedback and provide unity voltage gain and a very high input impedance. This design is known as a 'quasi-complementary' output stage, and is probably the most popular of all class-AB amplifier configurations; it calls for the use of three biasing diodes.

In Figure 10, both Q2-Q3 and Q4-Q5 are wired as complementary pairs of unity-gain common-emitter amplifiers with 100% negative feedback; they are mirror images of each other, and form a complementary output stage that needs only two biasing diodes.

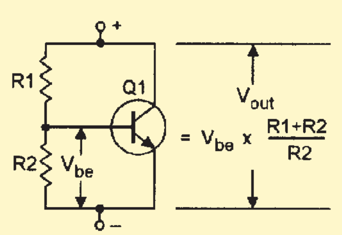


Figure 11. Fixed-gain amplified diode circuit.

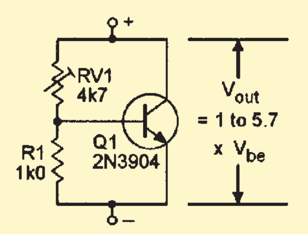


Figure 12. Adjustable amplified diode circuit.

The circuits of Figures 7 to 10 all call for the use of a chain of silicon biasing diodes. If desired, each of these chains can be replaced by a single transistor and two resistors, wired in the 'amplified diode' configuration described in Part 2 of this series and repeated here, in very basic form, in Figure 11.

Thus, if R1 is shorted out, the circuit acts like a single base-emitter junction diode, and if R1 is not shorted out, it acts like (R1+R2)/R2 series-wired diodes. Figure 12 shows the circuit modified so that it acts as a fully adjustable amplified silicon diode, with an output variable from 1 to 5.7 base-emitter junction voltages.

Another useful modification that can be made to the basic Figure 7 circuit is to add bootstrapping to its R1 collector load, to boost its effective impedance and thus raise the circuit's overall voltage gain (the 'bootstrapping' technique was also described in Part 2 of this series). Figures 13 and 14 show examples of bootstrapped class-AB power amplifier circuits.

In Figure 13, the Q1 collector load comprises R1 and R2 in series, and the circuit's output signal (which also appears across SPKR), is fed back to the R1-R2 junction via C2, thus bootstrapping R2's value so that its AC impedance is boosted by (typically) a factor of about 20, and the circuit's voltage gain is boosted by a similar amount.

Figure 14 shows a version of

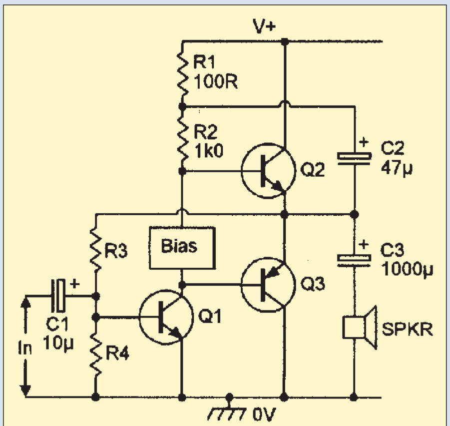


Figure 13. Amplifier with bootstrapped driver stage.

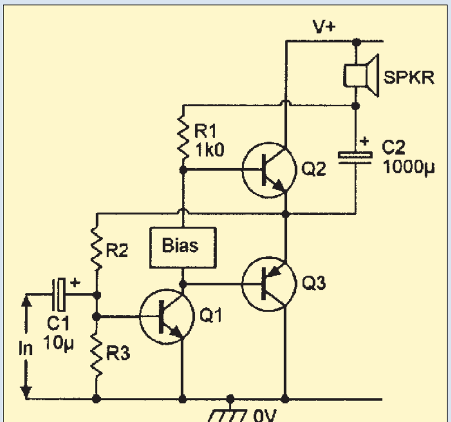


Figure 14. Alternative amplifier with bootstrapped driver stage.

the circuit that saves two components; in this case, the SPKR forms part of Q1's collector load, and directly bootstraps R1.

PRACTICAL CLASS AB AMPLIFIERS

The easiest way to build a class-AB audio amplifier is to do so using one of the many readily-available audio ICs of this type. In some cases, however, particularly when making 'one off' projects, it may be cheaper or more convenient to use a discrete transistor design, such as one of those shown in Figures 15 or 16.

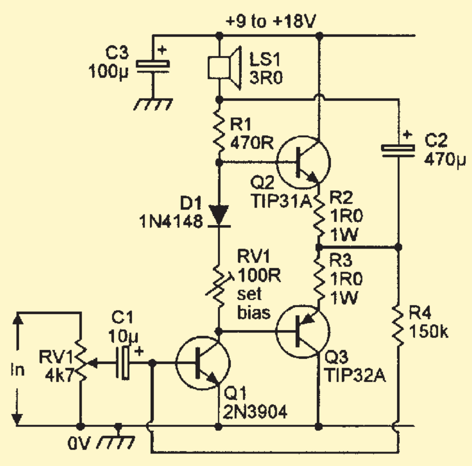


Figure 15. Simple 1 watt amplifier.

Figure 15 shows a simple class-AB amplifier that can typically drive 1W into a 3Ω speaker. Here, common-emitter amplifier Q1 uses collector load LS1-R1-D1-RV2, and drives the Q2-Q3 complementary emitter follower stage. The amplifier's output is fed (via C2) to the LS1-R1 junction, thus providing a low impedance drive to the loudspeaker and simultaneously bootstrapping the R1 value so that the circuit gives high voltage gain. The output is also fed back to Q1 base via R4, thus providing base bias via a negative feedback loop. In use, RV1 should be trimmed to give minimal audible cross-over distortion consistent with low quiescent current consumption (typically in the range 10 mA to 15 mA).

Figure 16 shows a rather more complex audio power amplifier that can deliver about 10W into an 8Ω load when powered from a 30 V supply.

This circuit uses high-gain quasi-complementary output stages (Q3 to Q6) and uses an adjustable amplifier diode (Q1) as an output biasing device. The Q2 common emitter amplifier stage has its main load resistor (R2) bootstrapped via C2, and is DC biased via R3, which should set the quiescent output voltage at about half-supply value (if not, alter the R3 value). The upper frequency response of the amplifier is restricted via C3, to enhance circuit stability, and C5-R8 are wired as a Zobel network across the output of the amplifier to further enhance the stability. In use, the amplifier should be initially set up in the way already described for the Figure 15 circuit.

ALTERNATIVE DRIVERS

In the basic Figure 7 circuit, the Q1 driver stage uses parallel DC and AC voltage feedback via potential divider network R2-R3. This circuit is simple and stable, but suffers from fairly low gain and very low input resistance, and can be used over only a very limited range of power supply voltages. A simple variation of this circuit is shown in Figure 17. It uses current feedback via R1-R2, thus enabling the circuit to be used over a wide range of supply voltages.

The feedback resistors can be AC-decoupled (as shown) via C2 to give increased gain and input impedance, at the expense of increased distortion. Q1 can be a Darlington type, if a very high input impedance is required.

Figure 18 shows an alternative configuration of driver stage. This design uses series DC and AC feedback, and gives greater gain and input impedance than the basic Figure 7 circuit, but uses two transistors of opposite polarities.

Finally, to complete this look at audio power amplifiers, Figure 19 shows a circuit that has direct-coupled ground-referenced inputs and outputs, and uses split power supplies. It has a long-tailed pair input stage, and the input and output both center on zero volts if R1 and R4 have equal values. The circuit can be used with a single ended power supply by grounding one supply line and using AC coupling of the input and output signals. This basic circuit forms the basis of many IC

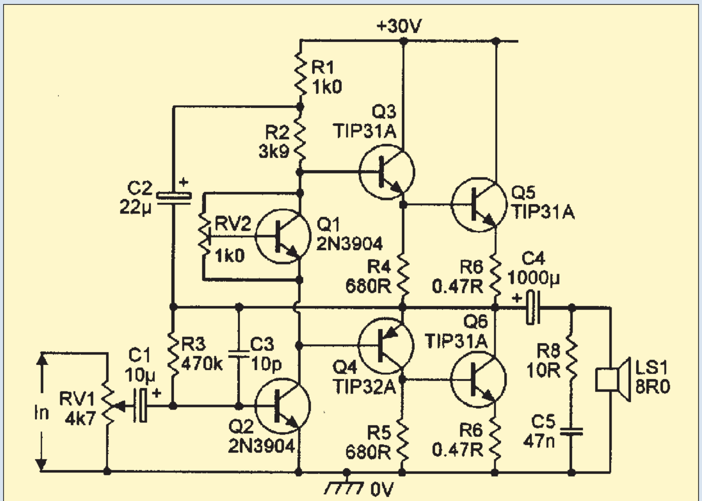


Figure 16. 10 watt audio amplifier.

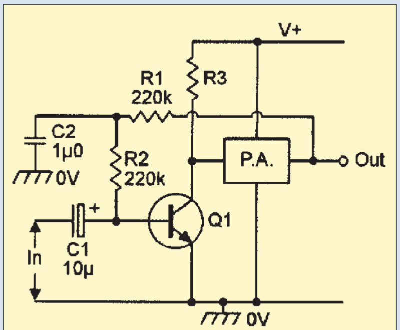


Figure 17. Driver stage with decoupled parallel DC feedback.

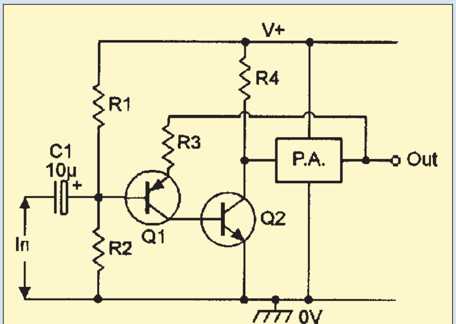


Figure 18. Driver stage with series DC feedback.

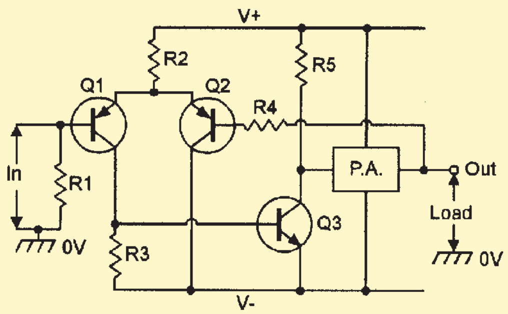


Figure 19. Driver stage with long-tailed pair input.

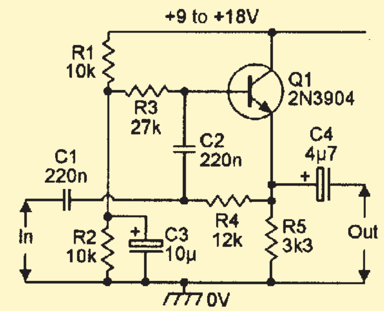


Figure 20. 50 Hz rumble or high-pass filter.

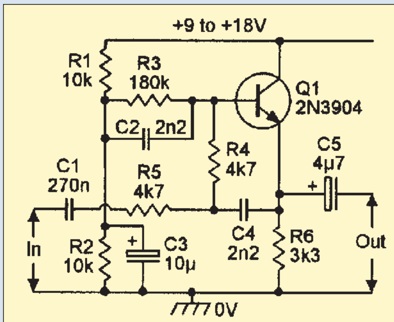


Figure 21. 10 kHz scratch or low-pass filter.

power amplifier designs.

SCRATCH/RUMBLE FILTERS

A common annoyance when playing old records (discs) through audio power amplifiers is that of scratch and/or rumble sounds. The scratch noises are mainly high-frequency (greater than 10 kHz) sounds picked up from the disc surface, and the rumbles are low-frequency (less than 50 Hz) sounds that are mostly caused by slow variations in motor-drive speed.

Each of these noises can be greatly reduced or eliminated by coupling the player's audio signals into the audio power amplifier input via a filter that rejects the troublesome parts of the audio spectrum. Figures 20 and 21 show suitable circuits.

The high-pass rumble filter of Figure 20 gives unity voltage gain to signals above 50 Hz, but gives 12dB per octave rejection to those below this value, i.e., it gives 40dB of attenuation at 5 Hz, etc. Emitter-follower Q1 is biased at half-supply volts from the R1-R2-C3 low-impedance point, but has negative feedback applied via the R3-C2-C1-R4 filter network. The circuit's frequency turn-over point can be altered by changing the C1-C2 values (which must be equal); thus, if the C1-C2 values are halved (to 110nF), the turn-over frequency doubles (to 100 Hz), etc.

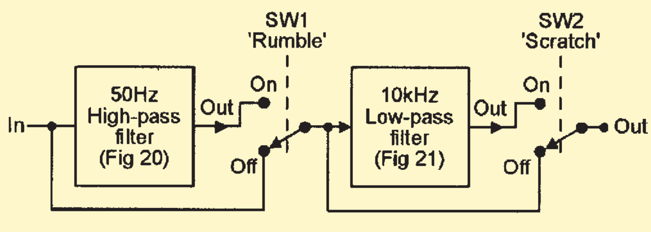


Figure 22. Complete scratch/rumble filter, with switching.

The low-pass scratch filter of Figure 21 gives unity voltage gain to signals below 10 kHz, but gives 12dB per octave rejection to those above this value.

This circuit is similar to that of Figure 20, except that the positions of the resistors and capacitors are transposed in the C2-R4-C4-R5 filter network. The circuit's turn-over frequency can be altered by changing the C2-C4 values, e.g., values of 3.3nF give a frequency of 7.5 kHz.

The Figure 20 and 21 circuits can be combined to make a composite scratch and rumble filter, by connecting the output of the high-pass filter to the input of the low-pass filter; if desired, the filters can be provided with bypass switches, enabling them to be easily switched in and out of circuit, by using the connections of Figure 22.

Note that if the Figure 20 and 21 designs are to be built as a single unit, a few components can be saved by making the R1-R2-C3 biasing network common to both circuits.

Next month's final installment will describe a miscellaneous collection of useful transistor circuits and gadgets. **NV**

Making Friends with a FIELD PROGRAMMABLE GATE ARRAY

by Chris Hannold

Way back when I was in the Boy Scouts, I was just getting interested in electronics. One of the first texts on electronics I ever picked up was a BSA Merit Badge Series booklet. This was meant to introduce young people to the world of electronics. From it, I learned how to read and draw schematics. I learned all the symbols and functions for resistors, capacitors, diodes, transistors, and even vacuum tubes. Yes, it was a while back. But, it did have a section based on digital electronics and that is where my fascination really took root.

I learned how to count to 16 in binary because they only talked about a four bit digital system. But, the booklet did get me started with digital logic and some basic integrated circuits. I earned my merit badge by building the Binary Coded Data (BCD) counting circuit in the back of the book. It had three IC chips, a seven-segment display and a four bit binary display. It counted from 0 to 9 displaying the number on the seven-segment display, and its binary counterpart on the four-bit display.

I'll be building the same circuit here, but I'm going to add a new twist. In one of m y frequent searches for robot projects on the Internet, I found one where the builder used a Field Programmable Gate Array (FPGA) to implement some logic. One of the cool things about it is that you don't have to change any hardware to change how the circuit works.

Starting With the FPGA

An FPGA is a single chip that can be programmed to act like nearly any other chip, combination of chips, or discrete logic gates. Some of the more advanced FPGA users are really into programming their FPGAs as microprocessors. As I'm learning to use mine, I'll be implementing some reflexive behavior logic for a mobile robot. But, my first project is the BCD counter.

After a quick search on the 'net, I found several development boards available but most of them were priced too far out of my range. The one I picked comes from a Canadian company called HVW Technologies (**www.hvwtech.com**). It is a single board that runs on five volts and is programmed through the parallel port of your computer. It comes with an Altera 7000 series FPGA and can be purchased for about $50.00 USD in kit form or for about $60.00 USD assembled (Figure 1.)

I bought mine in kit form and it is really easy to put together. However, the Altera chip is really sensitive to static electricity. Even though I used a grounded wrist strap, I had to send my unit back because the chip got zapped. I recommend that you buy the assembled version and ask them to program it for the first time with the sample program they offer in the instruction manual.

One other problem I experienced was the fact that my Windows XP machine wouldn't allow the development environment software to talk to the parallel port. According to HVW tech support, some but not all XP users have this problem. I'm not sure what the difference is with my PC, but I experienced the same problem with the Lego Mindstorms USB infrared tower. Luckily, I have a laptop running Windows 98.

After installing the MAX+PLUS Baseline software — provided on a CD-ROM and available free for download — I had no problems programming on the laptop. You will need to request and install a license file from Altera in order to get the software to work. That was no big deal since HVW provides a direct web link and instructions.

Programming the FPGA isn't difficult. There are a few methods. The first method, and probably the one with the highest learning curve, is to program it using a high level modular programming language in a text editor. It's a lot like programming any microcontroller. There are three languages built into the MAX+PLUS software. The Altera Hardware Description Language (AHDL) is available.

The Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) is also integrated into MAX+PLUS. Finally, the Verilog Hardware Description Language is in there, as well. Each of these languages is fairly easy to pick up with a little time, but I prefer the more visual method of using the graphic editor. The MAX+PLUS graphic editor is a schematic capture program that lets

you enter both simple and complex designs. With the symbol editor, you can view, create, and edit symbols that represent designs.

Those symbols can be used in schematics created with the graphic editor. The graphic editor also allows you to open an OrCAD schematic file and use it as your design. You can choose from libraries containing over 300 Altera-provided macrofunctions and primitives, or use your own custom macrofunction symbols that represent other design files, including other graphic editor files. A macrofunction is just a circuit that has been compiled and given a symbol of its own. After you get the BCD counter working, you could turn it into a macrofunction with its own symbol and use that single symbol in a whole new circuit.

There is a final method of programming your FPGA chip in the MAX+PLUS software. You can use waveform files. A waveform file will allow you to specify an input waveform and a required output waveform, and then have the software program your chip for you. I haven't tried this yet but it sounds interesting.

When you receive your development board, you should follow all the directions and make sure you can program it with the sample program provided in the instruction manual. It's called Majority Vote and is about as simple as it gets. Use this to get used to placing parts on the graphic editor screen and connecting them with wires. Take some time to explore the built-in part libraries, too. The help file is fairly extensive but I didn't see where they mentioned which chips and functions were in which libraries. Neither do they bother to give any data on any of the chips represented. I guess it would be way too much information. But, if you are like me, you already have an extensive datasheet collection on your computer.

Building the Counter

Though some other development boards do come with LEDs, switches, and other discrete components for testing, the one from HVW does not. That is one of the things I like about it. You can plug the board into a breadboard and have complete flexibility over your design. So, we'll have to add a couple things to complete the counter circuit. You'll need 11, 150 ohm, 1/4 watt resistors. You'll need a common anode, seven-segment LED numeric display. Finally, you'll need the breadboard, power supply, and some method for triggering the count.

A seven-segment display is an LED display made up of seven independent LEDs arranged to form a figure eight. In a common anode display, all the anodes of each LED are tied together so that you only need one positive supply input. In order to turn on one LED in the display, you supply a logic low on its corresponding input line. As in Figure 2, the input lines are labeled "A" through "G." Some displays have a decimal point available. Some have other things available. We'll only use the A through G inputs. Common cathode displays work the same way except all the cathodes of each LED are tied together and you must supply logic high to turn on the display LEDs. In any case, if you turn on the correct LEDs at the same time, you can form numbers from 0 to 9.

You can use a single resistor on the common anode pin to limit the current, if you wish. However, the LED display will be brighter when fewer segments are lit (like in the number 1), than it is when more segments are lit (like in the number 8).

When I built this circuit the first time, I used a light-detecting transistor to construct something similar to a barcode reader to trigger the count. You can use anything from a continuous pulse to a debounced switch. On this circuit, I used a debounced switch built from two inverters as shown in the diagram. Yes, I used a discrete chip instead of putting the circuit into the FPGA.

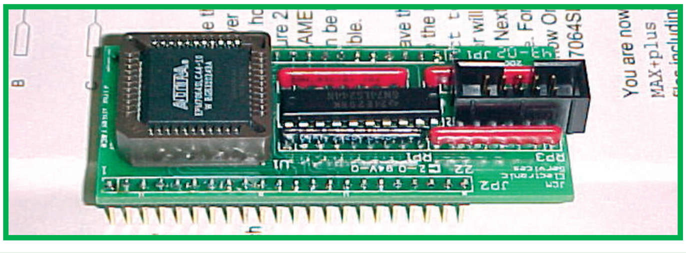
One reason is that I would most likely want to trigger the counter from outside the FPGA.

The other reason is that I could never get the debounce portion of the circuit to compile without errors. Apparently, only a tri-state buffer must drive the node — the wire carrying a signal between two logical components. In this case, a primitive — the input pin from the switch — drives it. The help file suggests placing a tri-state buffer between the input and the wire. Since the debouncing circuit loops back on itself so often, we'd need several tri-state buffers. It just seemed like a big waste of time to add all that when I'll be better served by using an outside trigger source.

Examine the regular schematic to see the chips and discrete components.

The first integrated circuit to look at is the 7490 Decade and Binary Counter. It contains four master-slave flip-flops and additional gating to provide a divide-by-two counter and a three-stage binary counter. The complete datasheet can be downloaded from Fairchild Semiconductor (**www.fairchildsemi.com**). The counter chip, with output A wired to input B, counts in binary from zero to nine and then recycles. The second integrated circuit is the 7447 BCD to Seven-Segment Decoder/Driver. It contains several logic gates wired together so that it brings in a four bit binary number and decodes it to turn on the correct output lines to form a

Figure 1. FPGA development board.



readable number on an LED display. The 7447 chip is capable of decoding and displaying four-bit data from 0 to 15. It has a few other interesting functions that aren't used in this project.

You can download the complete datasheet from Fairchild Semiconductor to find out about these. See the table in Figure 3 for the outputs by count. Note that logic low turns the display LED on. If you want to use a common cathode display turning on the LED with logic high, you should replace the 7447 with a 7448. You'll also have to change the way the resistors are wired. For the 7448, the output lines are connected straight to the LED and are pulled up to +5 VDC through the resistor.

The last integrated circuit is the 7404 Hex Inverter. It has six inverters, or "Not" gates. We'll only use four inside the FPGA. An inverter has a single input and a single output. If a high level is on the input, a low level is on the output. If a low is on the input, a high is on the output. Four inverters are connected to the outputs of the 7490 counter chip and turn on the appropriate single LEDs to display the binary representation of the number on the seven-segment display. In real life, the inverters are necessary to insure that there is enough current to drive the LEDs. They shouldn't be necessary in the FPGA circuit, but I included them for the sake of practice and staying true to the original design.

Now all you have to do is transfer the logic portion of the original circuit to the graphic editor as shown in the screenshot in Figure 4 and breadboard the rest of the circuit. Start up the MAX+PLUS software and call the new project "counter." Open a new graphic editor file by clicking <File> and <New> on the menu bar. Once the New File window opens, choose the Graphic Editor file type with the ".gdf" file extension.

Next, save the blank file as "counter.gdf" So you don't forget later, hit <Ctrl + Shift + J> to set the current project to the current file.

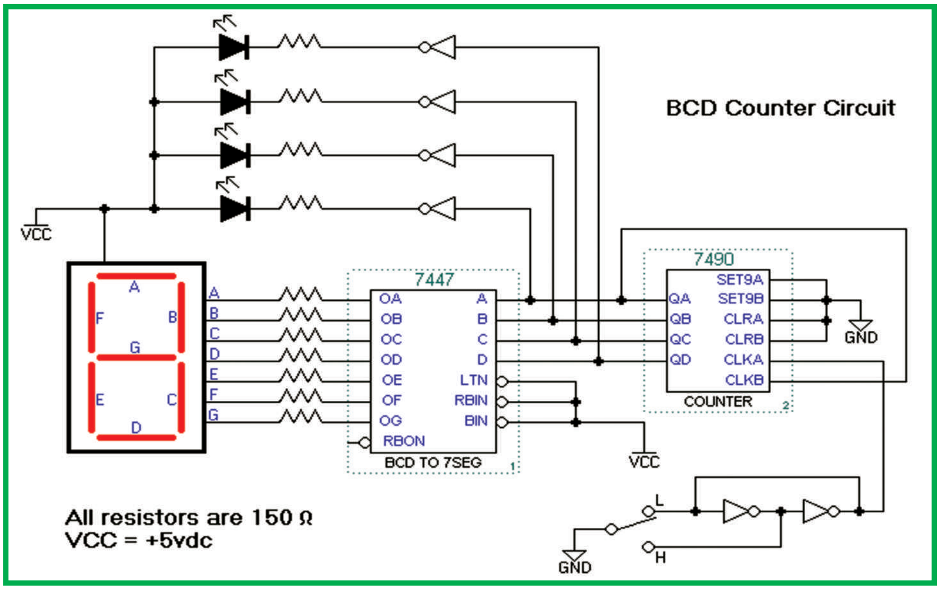


Figure 2. Counter schematic with debounce circuit.

Now you need to specify the FPGA being used. Select <Assign> <Device> on the menu bar. For Device Family, select MAX7000S. Clear the check mark for "Show Only Fastest Speed Grades." Go to "Devices" and select "EPM7064SLC44-10" and click OK.

Right-click somewhere on the blank file and select "Enter Symbol" from the dropdown menu. Choose the megafunction (MF) library and then double-click on the 7447 file. The chip should appear on the graphic editor screen. Do the same for the 7490 chip. You can choose the MF library for the 7404 chip,as well but it will only pop up a single "Not" gate and you will have to do it three more times to get the correct number of inverters on the screen. You can also copy the first inverter and paste three more on the screen.

Now you need to enter the sym-

Decimal or Function	Inputs						BI/RBO (Note 1)	Outputs							Note
	LT	RBI	D	C	B	A		a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	L	L	L	L	L	L	H	
1	H	X	L	L	L	H	H	H	L	L	H	H	H	H	

Figure 3. Truth Table for 7447.

bols for Gnd, Vcc, Input, and Output. This time, choose the primitive (Prim) library. You will only need one Gnd, Vcc, and Input. You will need 11 Outputs. It is possible to copy and paste these just like the inverters. Place all items in the same general vicinity as I have in Figure 5.

Once everything is on the screen, you can start wiring. You can use the same cursor to wire the project as was used to place components. If you can't get the wires to run in a neat manner, you can always choose the line cursor by clicking the line button on the sidebar. Either way, simply click and hold over an input and drag to an output.

Connect all the wires the same as shown in the diagram.

Before you compile the file, you need to rename the Input and Output pins. After renaming the pins to something logical — like where they connect to the display LEDs and Trigger — save the file. Then click the <Max+plus II> menu item and click on <Compiler>. When the compiler window pops up, click on start. Once the compilation is complete, a pop-up will appear informing you of any warning and/or error messages. A second compiler message window will also appear. It will contain any warning, error, or information messages generated by the compiler.

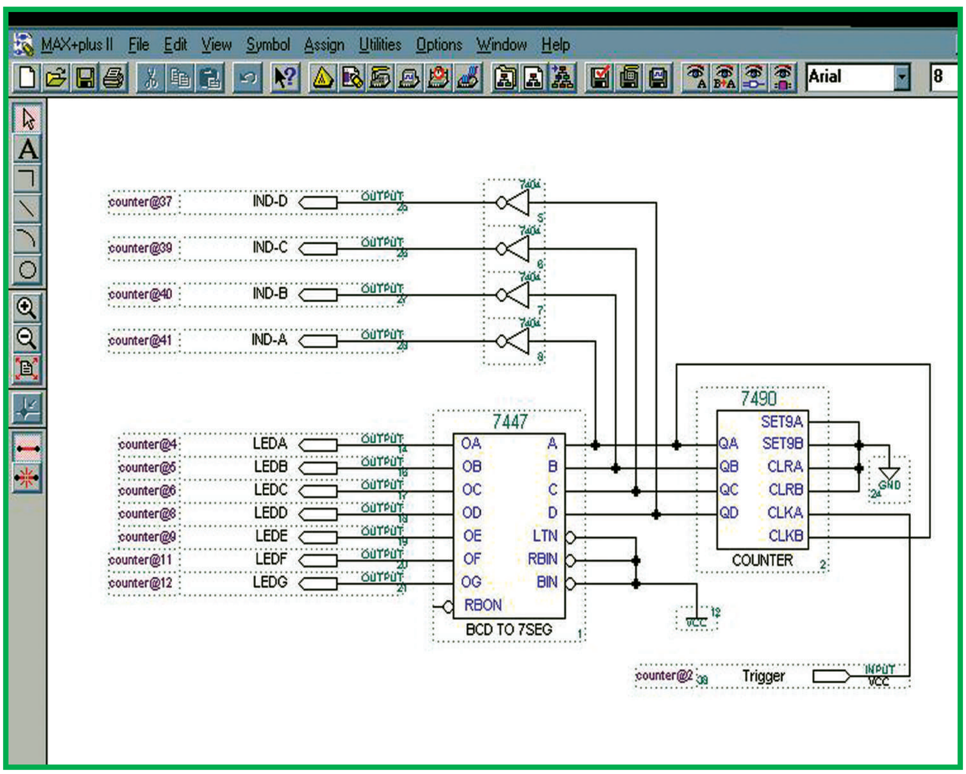


Figure 4. Screenshot of MAX+plus counter circuit.

In this case, you will get a green, "Not-gate pushback" information message. This message means very little to our project. If there is a red error message, there is a convenient "Help on Message" button available. Select the message you are curious about and then click the help button.

The compiler creates several files. The .rpt file shows which pins have been assigned as inputs and outputs. The .pof file is the file that is used to program the FPGA. The compiler assigns physical pins to your specified inputs and outputs, but you will probably want to change its choices. I did, and if you do, beware of the fact that the chip is mounted to a board meant for programming.

So, there are several multi-function pins that cannot be used as input or output even

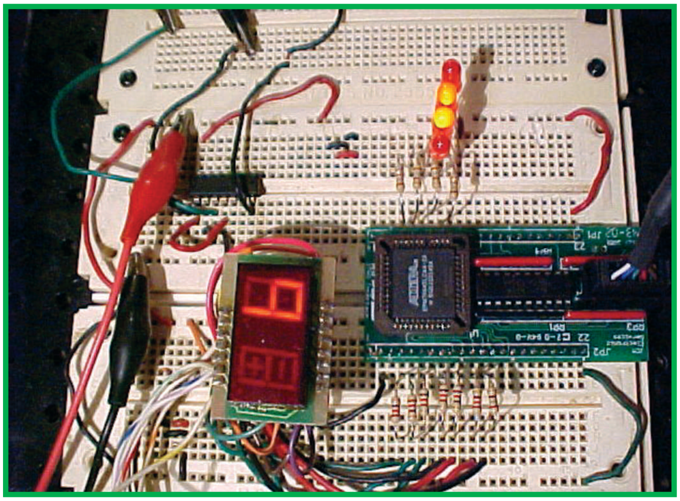


Figure 5. The breadboard.

though they are labeled as such.

This is because the board has the ability to interrupt anything the chip is doing in order to program it. This is not a big problem since there are still 28 regular input/output lines. Once you reassign the inputs and outputs to your preferred pins, those assignments will be displayed on the graphic editor screen. The new designations are to the left of all the input and output pins. If you do assign an input or output to a pin that cannot be assigned, the compiler will tell you.

Once everything compiles, you need to breadboard the circuit. Pin 1 is marked on the board. It is much like a 44-pin chip. The only power pins necessary are the ground (Gnd) on pin 22 and the +5 VDC (Vcc) on pin 23. Hook up all the resistors and LEDs. Turn the power on and pulse the trigger input to get the counter circuit to work.

If you look at my project picture (Figure 5) closely, you will see that I used half of a double digit, seven-segment display scrounged from old equipment. You'll also find the additional 7404 inverter chip I used to build the switch debounce circuit. You will also see the gray programming cable. It is not necessary to have the cable plugged in while the counter circuit is running, but it won't affect it if you do leave it plugged in.

I took a little chance in doing this project. Based on the sheer cool factor of having an FPGA in my next robotics project, I bought a board and spent time to learn how to program it. There were a few minor snags but once I got rolling, the job was easy.

I can hardly wait to try out the waveform functions. Since I am more of a visual, schematic type of person, I'll probably stick to the graphical editor but the hardware description languages may be right up your alley. In a future article, I plan to implement a bit of Rodney Brooks' subsumption architecture within the FPGA and build a small bot that can explore rooms, follow light, avoid obstacles ,and avoid falling down stairs. **NV**

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

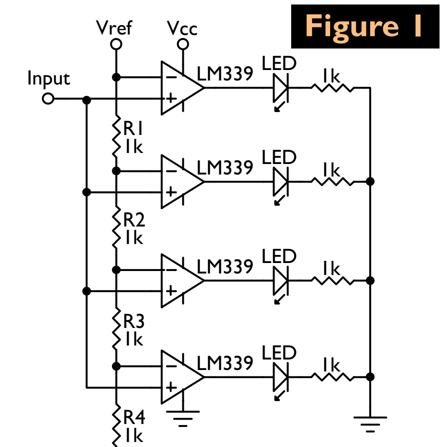
What's Up:

Test instruments galore, that's what. A handful of voltmeters, a diode, electrolytic capacitor ESR, and novel continuity tester. Finally, a reader takes up a Q&A design challenge and earns a year's subscription to *Nuts & Volts*.

LED Voltmeter

Q. I'm interested in building a voltmeter that shows the voltage level using a row of LEDs in a bar-graph. I plan on using this for a panel meter, so I only need one range of 0-15 V and I want to use 15 LEDs for the display. Do you have a schematic for this device?

Nicholas Olcan
via Internet



Basic Voltmeter

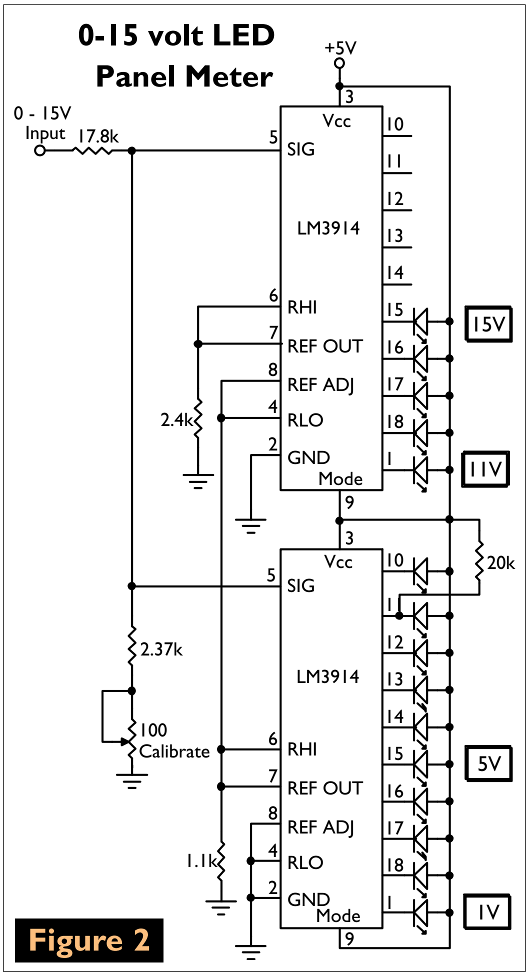


Figure 2

A. This is easily done using comparators; the basic circuit is shown in Figure 1. Each comparator is biased one step higher than the comparator under it. As the input voltage increases and exceeds the reference voltage on the comparator's inverting input, the output goes high and lights its respective LED. However, your request would require four of these chips plus 30 resistors. A better solution is the LM3914 Dot/Bar Display Driver. This IC contains 10 comparators with LED drivers, a buffer input op-amp, and a 1.2-volt reference. Only two ICs and four resistors are required to make a bargraph voltmeter that measures zero to 20 volts (Figure 2). Per your request, only 15 LEDs are shown, but it's easy enough to add the remaining five. The 100Ω pot is used to calibrate the voltmeter. If you don't have a suitable voltage reference for calibration, setting the pot to mid-range should provide 1% accuracy.

Name this Object

Q. I wonder if you can answer a very puzzling question.

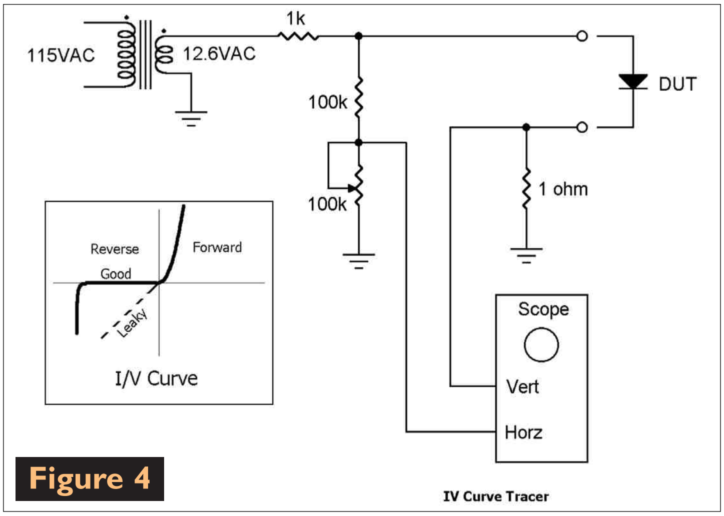


Figure 4

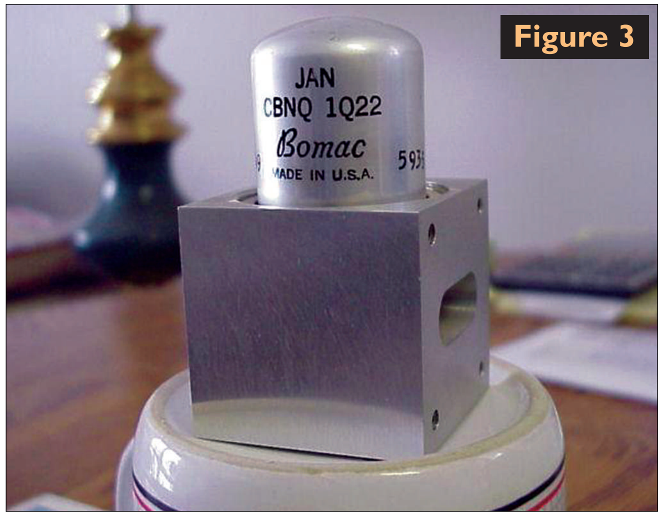


Figure 3

What is this thing (shown in Figure 3)? A friend gave it to me many years ago because he no longer had room for it, but it was so unique that he couldn't bear to throw it away — even though he never knew what it was. Now I am in the same situation. I don't know what it is either, yet I hate to throw it away, too.

It is very well made and appears to be some sort of wave guide fixture. A permanently-affixed vacuum tube with a glass base sits on the top, and there are no electrical connections of any sort coming from the tube. I placed the device on an overturned coffee cup to give you an idea of its size. Thanks for taking a look and your comments.

Lyle A. Nelson
Devils Lake, ND

A. It's an electron tube reference cavity, used to tune a microwave oscillator to 950 MHz. You can find its specs at **www.dscc.dla.mil/Downloads/MilSpec/Docs/MIL-PRF1/prf1ss296.pdf**

Testing Diodes

Q. I have a 240 volt, single-phase generator that sporadically browns-out with one of the 120 volt legs dropping to 85 volts. My oscilloscope shows some glitches in the output on that leg, and they get larger with increased load. This is a brushless type generator with rotating diodes on the armature. There is an electronic voltage regulator that changes a field voltage to control output, but it only senses one of the 120 volt legs. I suspect that one of the diodes is bad, but when I tested them with an ohmmeter, they passed okay.

Is there a bench test for this type of diode (1300V/3A)?

Bill Daley
via Internet

A. Semiconductors are strange devices in that they don't wear out like vacuum tubes or mechanical parts. Their failure is generally catastrophic — either they are dead or alive. However, semiconductor characteristics can change with age. In diodes, the aging process usually manifests itself in the form of increased leakage current. This situation (increased leakage) is exacerbated by higher temperatures, like those found inside heavily-loaded generators. Testing with an ohmmeter won't reveal this flaw.

A better way to gauge diode performance is with a curve tracer, shown in Figure 4. This circuit plots the voltage and current on the screen of an oscilloscope as the voltage across the Device Under Test (DUT) changes amplitude and polarity. The diode should begin forward conductance at about one volt. When the reverse voltage exceeds the breakdown voltage of the diode junction, the diode goes into the avalanche mode (zener region) and begins conducting. With your high-voltage diodes, though, this test will never place the diode in the zener region unless it's really on its last leg. It will, however, tell you if there's excessive leakage because the reverse curve will sag.

Don't have an oscilloscope? Reverse leakage current can be measured using a microammeter in series with a power supply, as shown in Figure 5. The HI/LO switch selects the test voltage. In the LO position, the voltage across the diode is less than 50 volts; in the HI position, it's less than 200 volts. A good diode will have less than 0.1 µA leakage. Anything above that is suspect.

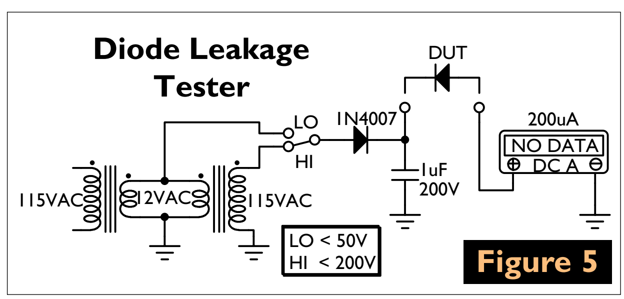


Figure 5

Capacitor ESR Tester

Q. I have repaired a number of high current DC power supplies. Rather than replace all the main filter capacitors (expensive), I would like to

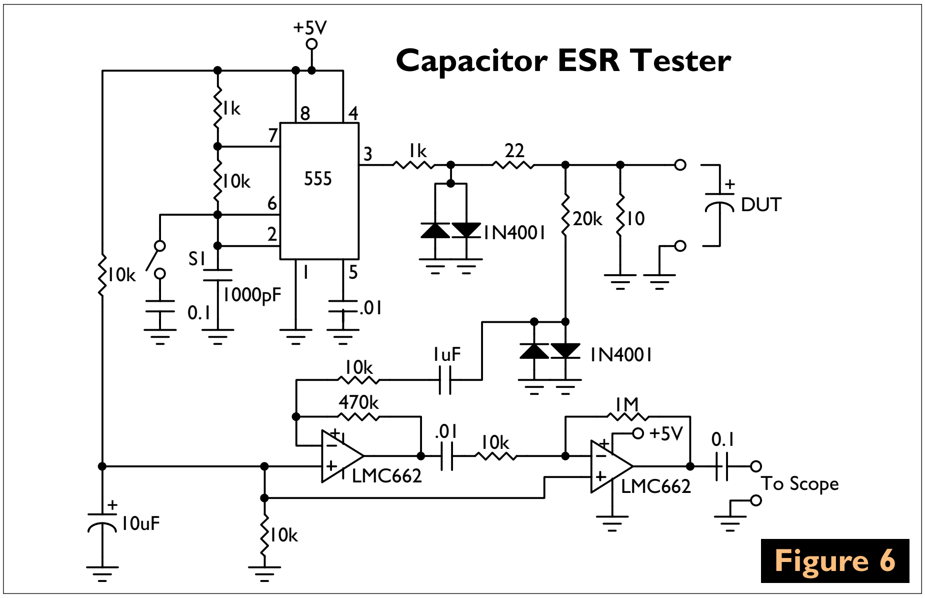


Figure 6

test the output for the AC ripple voltage. I use a digital voltmeter and need to know if a DC blocking capacitor is needed, and its value. Also, what is an acceptable ripple level in millivolts?

Paul Frankle WD4LIQ
via Internet

A. What causes a filter capacitor to fail isn't because its capacitance decreases, but rather because its ESR value increases. ESR acts like a resistor in series with a capacitor (hence the name Equivalent Series Resistance). It includes resistance of the dielectric, plate material, electrolytic solution, and terminal leads at a particular frequency. As a capacitor's ESR increases, so does the ripple voltage across the capacitor.

A simple ESR tester is shown in Figure 6. The heart of the tester is a 555 square wave oscillator running at about 100 kHz. The resistor values (1K and 10Ω) are selected to knock down the signal to 100 mV, which means you can use this unit as an in-circuit tester (turn off the power!). The diodes are inserted to protect the tester should you accidentally attach it to a charged capacitor. The op-amps are needed to bring the signal up to a level where it's readily displayed on any oscilloscope, even those with lesser sensitivity like a converted PC sound card oscilloscope. The instrument can be calibrated using a standard film resistor (non-inductive).

At 100 kHz, ideal capacitors of 10 µF or greater appear as a short circuit to the AC test signal. Capacitors in the 0.1 to 10 µF range with an ESR of 2Ω or more will distort the square wave, causing its top to progressively tilt as the capacitance decreases. This is the result of the capacitor charging up as it integrates the test signal. A shorted capacitor will not integrate the signal.

At the other end of the scale — capacitors of 10 µF and larger — it's virtually impossible to distinguish a low ESR capacitors from a shorted one. Don't forget that the ESR is frequency dependent, though. So as the frequency changes, so will the ESR. A shorted capacitor won't show this characteristic. For example, at 500 Hz (S1 closed), a 2200 µF cap will show the tilted effect displayed by a 3.3 µF cap at 100 kHz.

An AC voltmeter can be substituted for the oscilloscope — with reservation. Most DMMs can't stretch to 100 kHz, and few can measure beyond 10 kHz. Fortunately, the problem is easily resolved using the circuit in "AC Millivoltmeter DMM Adapter" below.

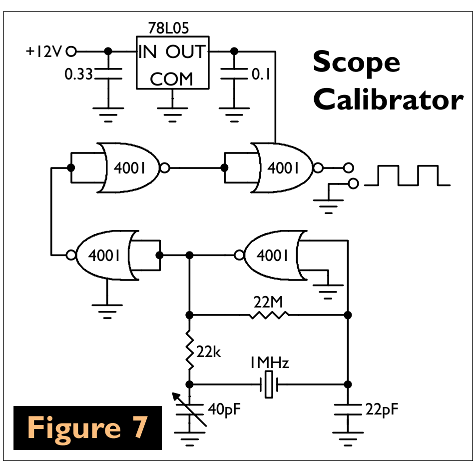


Figure 7

Scope Calibrator

Q. I have an older oscilloscope that lacks a scope calibrator. I would like to build a square wave generator of about 1 MHz with a peak-to-peak voltage of exactly 5 volts. I can use this waveform to both calibrate the vertical scale and adjust the compensation of the scope probe. What do you have?

Mark Farrall
via Internet

A. Your best bet would be to start with a 1-MHz crystal oscillator, then buffer its output so that it's isolated from the load (your test probe), like the circuit shown in Figure 7. The 78L05 regulator holds the output voltage stable within five percent of 5 volts, which is plenty adequate for all but the most demanding work. Although I specified the input voltage at 12 volts, it's only because 12 volts is a common source in most test instruments. Any voltage between 7 and 35 volts will work. Because the oscillator is crystal controlled, the output waveform can be used as a reference to calibrate the time base (each pulse is 0.5 µS wide, one cycle is 1 µS); this time base is stable to better than .001%; use the 40 pF trimmer capacitor to pull the oscillator frequency one way or the other.

AC Millivoltmeter DMM Adapter

Q. I am a dyed-in-the wool Analog Guy who doesn't particularly

care much for the new digital world. As a result, I often breadboard audio circuits just for the fun of it. But one of the casualities of the digital revolution is that it is hard to find affordable audio test equipment, like an AC millivoltmeter. My DMM has exactly two AC ranges: 200 volts and 750 volts, which are worthless for measuring one volt audio signals. Do you have a simple circuit that would allow me to use my DMM as an AC millivoltmeter?

AnalogGuy
via Internet

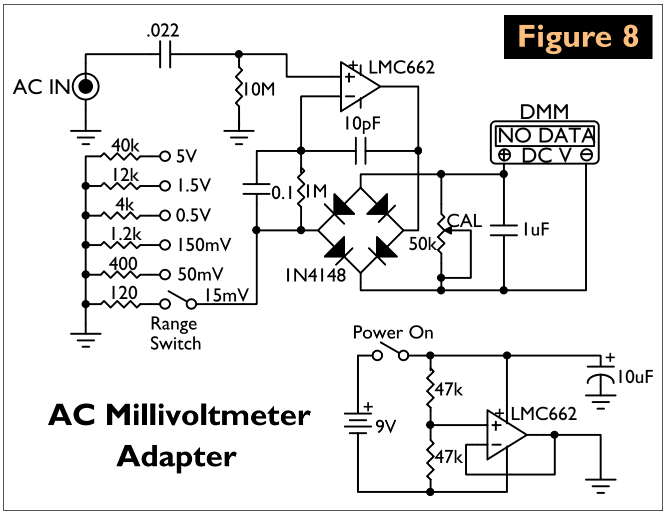


Figure 8

AC Millivoltmeter Adapter

A. I was in the same predicament just last year when I was doing filter designs for this column. Don't get me wrong, a scope works great, but it just doesn't replace a meter for instant voltage readings. Figure 8 illustrates what I came up with.

While the circuit may look confusing, it's really nothing more than a precision full-wave rectifier with the output of the op-amp balanced through the bridge rectifier to the inverting input. In the feedback loop are the Range Switch resistors which set the gain of the op-amp. I normally set the DMM to the 2000 mV range, then use the 50K pot for calibration. In most instances, I'm not concerned with the actual voltage, but the relationship between input and output voltages so exact calibration isn't a factor.

Proper calibration requires a precision AC reference voltage. While the accuracy will only be 5%, you can do this using the "Scope Calibrator" circuit above and adjusting the DMM for a 2.5 volt reading – the average DC voltage of a 5 volt square wave. To get an RMS equivalent, adjust the reading to 3.5 volts (2.5 x 1.4).

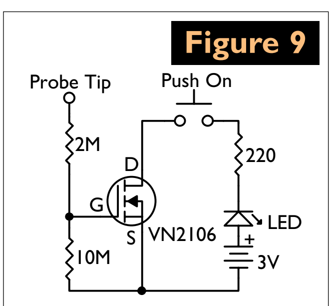


Figure 9

DC Test Probe

Wireless Voltage Test Probes

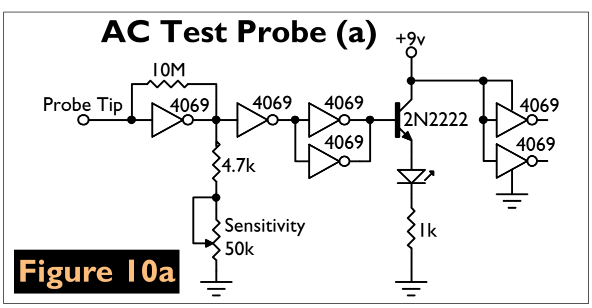
Q. In various catalogs I've seen pen-style probes for testing 12 volts DC and 110 volts AC. The one thing they have in common is that none of them require a ground wire. You simply touch the tip to the voltage source and an LED lights. Do you know what makes these gadgets work?

Frank D.
Ontario, Canada

A. Body resistance. Your body, which readily conducts current, acts like the missing second test lead. Take the circuit in Figure 9, for example. The VN2106 is an enhancement field-effect transistor that conducts when the voltage on the gate (G) exceeds 2.4 volts. This causes current to flow through the LED and turns it on.

Let's say you want to test your car battery using this probe. If you hold the test probe in one hand with your palm touching the three volt battery negative terminal, and touch your other hand to the body of the car, you connect the bottom leg of the circuit to the 12 volt battery ground. When the probe tip is touched to the +12V terminal of the battery, the circuit is complete and the LED lights.

AC probes work in very much the same way, with your body resistance supplying the ground connection. The basic circuit is built around a 4069 hex inverter (the generic equivalent of the 4049 with less drive current). See Figure 10(a). When the probe tip is touched to a live AC wire, the LED lights. Because the AC signal is pulsating and not steady-state like the battery in Figure 9, it can be used to flash an LED for an added attention getter, like the circuit in Figure 10(b). This version of the AC probe uses a 4017 decade counter that ripples through the outputs as the AC signal pulses its input. Each time the Q0 output goes high, the LED lights. However, there is a 1 in 10 chance that the LED will remain lighted when the input is removed, but it's easy enough to tell there's no voltage present because it's not blinking.



AC Test Probe (a)

Figure 10a

RPM to Hertz

Q. I often have to run my house off an auxiliary generator. My prob-

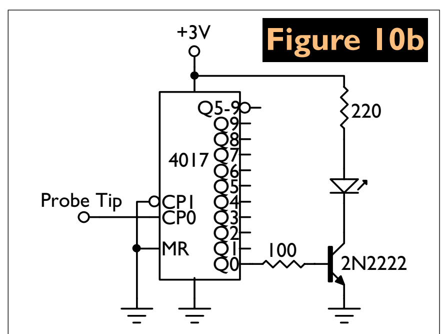
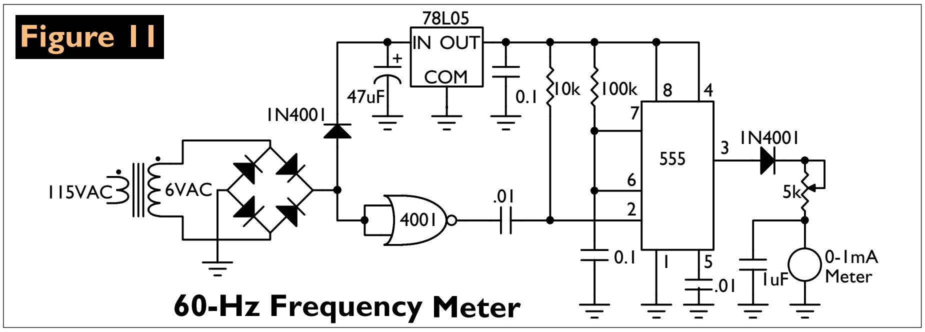


Figure 10b

AC Test Probe (b)

Figure 11



60-Hz Frequency Meter

lem is that I can't be sure that the generator's frequency matches that of the line frequency. I kinda remember that there used to be reed frequency meters that would indicate this, but I haven't seen one for sale in a long time. Do you have a circuit that will tell me when the frequency is right on frequency or if it's high or low? I will use this information to adjust the idle.

Bob Haskett
via Internet

A. Fair Radio Sales (419-227-6573, **www.fairradio.com/panelm.htm**) still sells a frequency panel meter based on reed vibration, but only for 60 Hz and 400 Hz. If your generator is out of tune, the meter won't tell you if it's on the high or low side. But the meter in Figure 11 will.

The 555 is configured as a monostable multivibrator (one-shot) that I'm using as a frequency meter. Each time pin 2 is grounded, the monostable fires and generates a 10 mS output pulse. The 4001 gate sharpens up the negative-going transition of the sine wave and provides a clean pulse to the 555 through the .01 µF capacitor. The meter averages the pulses to indicate the frequency. The higher the frequency, the higher the meter reading. The meter is calibrated by plugging the transformer into a standard AC outlet and setting the meter pointer to half scale using the 5K pot. This mark represents your 60 Hz reference. When the instrument is connected to the generator, adjust the RPM of the generator so that the needle rests on that mark and you will have a solid 60 Hz output.

Audible Continuity Tester

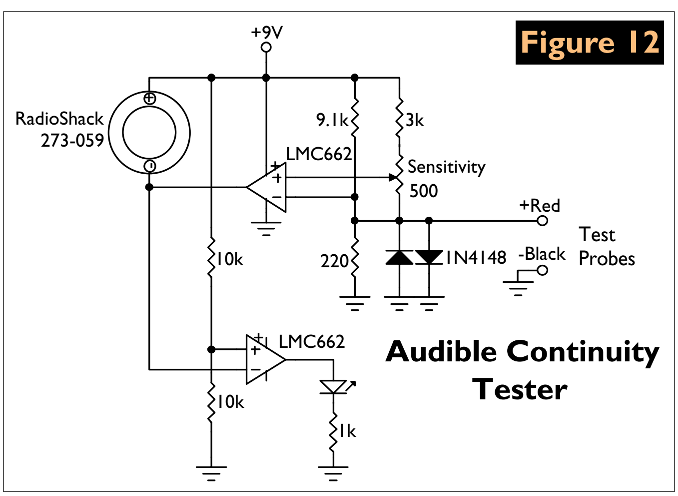
Q. How about some help on a circuit for an audible continuity tester that will have a sensitivity of only a few hundred ohms at worst? The tester I have squawks at connections as high as 25,000 ohms.

Michael Herman
via Internet

A. The following circuit (Figure 12) is based on a NASA design from the 80s. I've upgraded it just slightly to take advantage of today's superior ICs. Built around an LMC662 op-amp acting as a comparator, the tester can be adjusted to indicate continuity for resistance up to 35 ohms and no higher.

For example, if you set the sensitivity to 30 ohms, the tester will emit a tone if the resistance between the probes is 30 ohms or less. If the resistance is 30.2 ohms, the buzzer remains silent. I also threw in an LED for visual effect, but mostly because I had an empty op-amp to contend with. The tester is easily calibrated using a fixed resistor. As an added bonus, the parallel diodes (1N4148) limit the voltage across the probes to 0.6 volts, which means you can use the tester in-circuit (with power off!) without fear of damaging sensitive semiconductor devices.

Figure 12



Audible Continuity Tester

Reader's Circuit

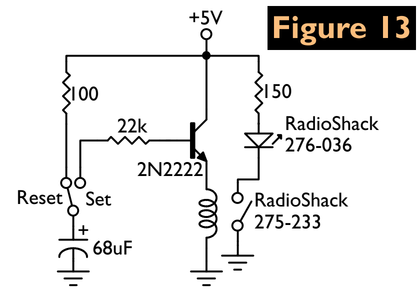
I am writing in response to your 555 reader quiz in the Nov. 2003 issue, where you asked for a simpler design to flash an LED for 10 seconds then stop until reset. What I finally wound up with was a 68 µF capacitor that I used as a timer to control a relay connected to a cheap RadioShack flashing LED. When the Set/Reset switch is moved to the left, the cap charges through the 100Ω resistor. Moving the switch to the right discharges the cap through the base of the 2N2222 transistor, which, in turn, closes the relay contacts and applies voltage to the blinking LED. When the current through the relay falls below its threshold level, the relay drops out and disconnects the LED. That's all there is to it. The circuit, shown in Figure 13, is auto turn-off and draws no power except for leakage through the transistor (which is less than the natural discharge current of the battery itself).

Clayton D. Johnson
Houtzdale, PA

Editor's Note

Over the years, I've been asked several times for a noise canceling circuit that would eliminate background noise, such as office din or chugging engines. Although there is still no "blanket" solution to annoying sounds — like snoring — the technology has advanced far enough that noise-canceling

Figure 13



Flasher LED Timer

headphones are a reality. And I'm happy to report that their prices are coming down. In MCM's (800-543-4330; **www.mcminone.com**) most recent catalog, they advertise Pro-Luxe noise-canceling headphones for just $24.95 (Order# 35-1115) — a far cry from the $299.00 that Bose is asking for their QuietComfort noise-canceling headphones. I haven't had a chance to test them, but for the price, it's worth a try. Even if they aren't perfect at canceling noise, you still end up with a great pair of headphones.

TJ Byers
Q & A Editor

MAILBAG

Dear TJ,

In the June 2003 issue you suggested that I use the free AutoTrax PCB layout program. I do not have Internet access but managed to obtain a copy on CD from my brother. I printed out and read the README file but it's not an operations manual. Where do I get the instructions on how to use AutoTrax?

In the same issue, you mention that Futurlec (**www.futurlec.com**) will make PCBs up to 30mm by 30mm. That size limitation is totally impractical. Is it possible it should have read 30cm by 30cm?

Ken Stone
Cherryvale, KS

You can find the manual on-line at the following website:

www.autotraxeda.com/docs/AutoTRAX/autotrax.htm

And yes, that was a typo. The board size is 30cm by 30cm priced at $0.03 per square centimeter, or $0.20 per square inch.

TJ Byers
Q & A Editor

Cool Web Sites!

How many megabytes are there in a yottabyte?
www.webopedia.com/quick_ref/FileSizeConversionTable.asp

A beginner's guide to filter topologies
www.maxim-ic.com/appnotes.cfm/appnote_number/1762/ln/en

Think you know about all the features of Google? Did you know about the scientific calculator?
www.google.com/help/calculator.html

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

An Industrial Cup o' Joe

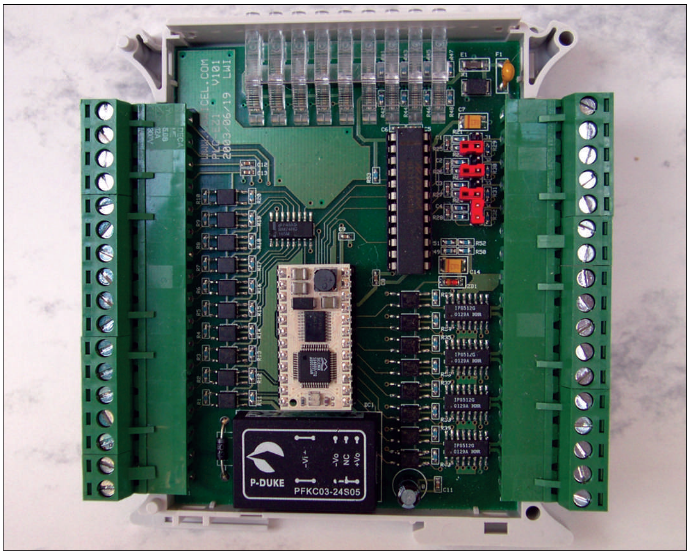
Real-world Control Through Java — On a Stamp!

It's no secret that for as long as Stamp microcontrollers have existed, Stamp customers have been very industrious ... and now, with a little help from the Stamp PLC, Stamp users can have a nice product that will help them get industrial.

The Stamp PLC isn't the first time Stamp modules have been fitted for an industrial environment, but it does offer a package that is more similar to large scale, high-dollar products — and is a good fit when a "standard" PLC (and its expensive development software) isn't required. One of my first "pro" uses of a BASIC Stamp was to replace a $1,200.00 PLC that wasn't behaving as desired (it was part of a trade show display). When the display company couldn't reprogram the PLC (they had farmed out that task), my boss asked me to "fix" it. I did by replacing the PLC with a BASIC Stamp 1 module and some triacs. My boss was happy, the display looked and worked great, and my employer saved about $1,150.00.

The Stamp PLC was developed for Parallax by Lawicel HB of Sweden. Lawicel HB specializes in industrial applications and has found the BASIC Stamp quite useful in many projects. With their considerable expertise, they've designed an elegant, industrialized enclosure for 24-pin Stamp modules that fully protects the inputs and outputs (optical isolation), has visual indicators for digital I/O ports, provides for an optional four channel, 12-bit ADC, and has a clean power supply for the circuitry. As would be expected, the Stamp PLC mounts on a standard DIN rail, and can be powered with 18 to 36 volts DC (24 VDC is standard for industrial applications). Finally, professionals will appreciate that the Stamp PLC meets the requirements to carry the CE certification mark.

Figure 1. Inside the Stamp PLC.



Since we're starting a new year, I thought I'd try something different. As the code for the Stamp PLC is not particularly complex, what I thought I'd do is compare code for two different Stamp modules: the stock BS2 and the Javelin Stamp (my choice for Stamp PLC projects).

Whoa ... this is different; two languages in one article. Yes, it is. The reason for it though is that many BASIC Stamp users have been experimenting with the Javelin and some are not being as successful as they would like to be right out of the gate. Part of that is human nature; the BASIC Stamp is very easy to use and the Javelin Stamp is quite a sophisticated little beast and takes a bit of time getting used to, especially for those that haven't programmed in Java or C. That doesn't mean that the Javelin is difficult to use, it's just different. By looking at listings side-by-side, it may help those wanting to work with the Javelin get up and running, ultimately taking advantage of some of the Javelin's unique features.

Do keep in mind that the Javelin is still a new kid on the block, and has a lot of really great features that aren't yet available in BASIC Stamps. The timer object, for example, is very useful in the Stamp PLC and you'll see how it gets used to set the I/O scan and process interval to a specific rate. Okay, then, let's crack open the Stamp PLC and get started.

Pick a Stamp ... Any 24-pin Stamp

To be perfectly honest with you, one of the trickiest aspects of the Stamp PLC is opening the enclosure so

that we can install our 24-pin Stamp. Again, the enclosure is designed well and intended for a grungy industrial environment, so there's no slop. On the back (opposite the I/O connections label), you'll find three slots where you can use a small screwdriver to release the locking tabs that hold the case halves together. Go slowly, as the DIN rail lock is spring-loaded and if you're not careful, it can go flying. (Ask me how I know ...)

Once the case is open, you'll see two sockets: a wide 24-pin socket for the Stamp and a skinny DIP socket for the optional MAX1270 ADC. Install the Stamp so that pin 1 is oriented toward the input connectors; do the same for the MAX1270.

Before we put the Stamp PLC back together, we need to configure the MAX1270 input channels. We have two choices: voltage or 4-20 mA inputs. Adjacent to the right side of the MAX1270, you'll see a line of eight header posts; these are organized as two posts for each channel. If we want to measure voltage (which is software configurable for various ranges), we leave the jumper out. If we want a particular channel to measure a 4-20 mA current signal, we need to add the jumper. Figure 1 shows the inside of my Stamp PLC with a Javelin installed, the MAX1270 installed, and channel four of the ADC inputs configured for a 4-20 mA current signal.

What's In a Name?

Those of you that know me know that I am a bit of a maniac when it comes to what I consider "proper" code writing — a big part of that is using well-planned constant, variable, and label names to make writing, reading, and especially debugging my code a lot easier. Technically, PBASIC has no formal standards for naming and formatting, but many of us have adopted standards used by other flavors of BASIC (notably, Visual BASIC).

My experience is that Java is less tolerant of free-form (sloppy) formatting, and there seems to be a standard that most Java programmers follow. The standard that I follow is articulated in the book, *The Elements of Java Style* (ISBN: 0521777682). I enjoyed this little book so much that I used it as a model for a short document called *The Elements of PBASIC Style* that demonstrates how we at Parallax are now formatting our programs (this is an on-going process, so older listings do not reflect this standard).

You can download the PBASIC style document from the Parallax website.

Let's start with some hardware definitions. The BASIC Stamp first:

```
Clock            PIN     0
Ld165            PIN     1
Di165            PIN     2
AdcCS            PIN     3
AdcDo            PIN     4
AdcDi            PIN     5
```

Okay, these are easy. Now let's look at the same pin definitions in the Javelin Stamp:

```
static final int CLOCK     = CPU.pin0;
static final int LD_165    = CPU.pin1;
static final int DI_165    = CPU.pin2;
static final int ADC_CS    = CPU.pin3;
static final int ADC_DO    = CPU.pin4;
static final int ADC_DI    = CPU.pin5;
```

Okay, before you run out the door screaming ... take a deep breath, it's not so hard. What I can tell you is that setting up a program in the Javelin does require a bit more effort. What you'll find, though, is that as the program grows very large, things get easier to deal with in the Javelin versus the BASIC Stamp, especially since the Javelin allows us to have 32K of contiguous memory and a bunch more variable space. When we get into reusable class modules, it's a whole new world.

Let's press on. The keyword "static" is very important as it allows us to define a constant, variable, or method (a Java function or procedure) as part of a class instead of as part of an object. What this lets us do is use that constant, variable, or method without declaring an object. An example of this is the CPU class that declares many static values

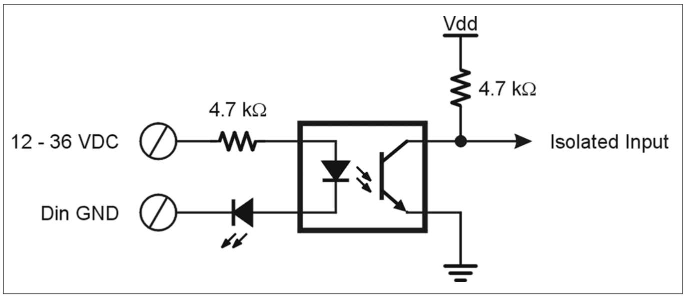


Figure 2. Optically-isolated Digital Input Circuit.

and methods that we'll use in this program. The keyword "final" makes the value a constant. As Java is a strongly-typed language, we use the "int" keyword to specify the size of our definitions. An int is a 16-bit signed value.

Notice that, as I just mentioned, we're setting our constant (final) values to static values from the CPU class. The CPU class is specific to the Javelin (you won't find the CPU class elsewhere) and its purpose is to define values and methods that are required for embedded control applications — many times mimicking BASIC Stamp functions. The values for I/O pins are not quite as simple as you might imagine; this is due to the requirements of the methods for writing to and reading from a pin. We don't have to remember the pin values though, as they are defined as constants for us.

Let's Get Digital

The bulk of the Stamp PLC's I/O connections are digital: 10 digital inputs and eight digital outputs. One thing to note is that both are on separate electrical systems; this is by design for protection. The digital inputs will take anything from 12 to 36 volts, and have their own ground connection (marked Din GND). The reason for the Din GND connection is that the inputs are optically-isolated from the rest of the circuit.

That way, if a high-tension line gets across one of our inputs (accidents do happen), we'll lose the opto-isolator but protect the rest of the device. Figure 2 shows a schematic of the input isolation.

When no input is present, the 4.7K pull-up holds the isolated input line high. When we do get an input signal, the transistor side of the opto-isolator will conduct, pulling the isolated input line low. Note that the input signal is actually driving two LEDs: one in the opto-isolator, the second is the visual indicator that lets us know that an input pin is active.

There is actually a second stage between most of the input isolators and the Stamp: a 74HC165 shift register. The 74HC165 allows us to get eight inputs using just three Stamp pins. We've used the 74HC165 before, but for review, we use it like this: "blip" the Load line low momentarily to load the inputs, then use **SHIFTIN** to move them into the Stamp.

The 74HC165 does us another favor: it inverts the inputs — this is great as the opto-isolators invert our Din1-Din8 inputs. The way this works is by using the inverted serial output line so that we end up getting a "1" bit for active inputs on Din1-Din8. Figure 3 shows the connections for a 74HC165 that uses the inverted data output (QH\) line.

The other two Stamp PLC inputs — Din9 and Din10 — connect directly to the Stamp after the opto-isolator stage so we have to invert them in software. This is easy for both Stamps.

Okay, here's the code for reading the digital inputs with the BASIC Stamp:

```
Read_DigIns:
  PULSOUT Ld165, 15
  SHIFTIN Di165, Clock, MSBPRE, [dinLo]
  dinHi = 0
  din9  = ~Di9
  din10 = ~Di10
  RETURN
```

A no-brainer, right? Absolutely. **PULSOUT** is used to load the inputs and **SHIFTIN** moves them into dinLo. Since we're using the inverted output from the 74HC165, a low (zero) on any of its inputs will be clocked in as a high (one) to the Stamp. The next few lines read Din9 and Din10 directly, using the invert operator (~) to correct the input polarity from the opto-isolator stage. At the end of the routine, we have a word-sized variable (digIns) that holds the current state of our digital inputs.

Let's have a look at the same code in the Javelin:

```
static int readDigInputs() {

  int inBits;

  CPU.pulseOut(1, LD_165);
  inBits = CPU.shiftIn(DI_165, CLOCK, 8, CPU.PRE_CLOCK_MSB);

  if (CPU.readPin(DI9) == false) {
    inBits |= 0x100;
  }
  if (CPU.readPin(DI10) == false) {
    inBits |= 0x200;
  }

  return inBits;

}
```

Yes, it looks a bit different but I think that you'll agree that the similarities are, in fact, greater than the differences. The first thing we notice is that our method called readDigInputs() is defined as "static int" — this should make sense based on our earlier discussion. This method is part of our class (not an object) and the result is going to return an integer value to the caller (main part of the program or other methods). Next, we define a local (temporary) variable to hold the inputs before we return them to the caller.

What follows are two lines of code that have a direct

correlation to the PBASIC example above. As I stated earlier, the CPU class contains methods for embedded control, many that are duplicates of PBASIC functions. Aside from the basic syntax adjustment, the only item of note is that the CPU.shiftIn() method requires a bit-width value.

The next section reads the direct inputs, albeit indirectly. You see, Java doesn't know anything about hardware like PBASIC does. So the Javelin provides another method in the CPU class called readPin() that will do this for us. This method will return true if the input is high, false if the input is low. Since our direct inputs are active-low, we will add the appropriate bits to the inBits value. If you've never programmed in C or Java, this line may look odd:

```
inBits |= 0x100;
```

In Java (as in C), there are occasional programming shortcuts that save us some typing. Here's the long version of that line:

```
inBits = inBits | 0x100;
```

And if we had to do it that way in PBASIC, it would look pretty much the same:

```
inBits = inBits | $0100
```

Once all the bits are collected, we return them to the caller. This comes in handy when we want to look at all the input pins, and is an aid when we want to check the status of just one. Let's have a look at a method for checking a single input:

```
static boolean readDigIn(int digIn) {

  int mask;
  boolean active;

  if (digIn <= DIN10) {
    mask = 0x001 << digIn;
    active = ((readDigInputs() & mask) == mask);
  }
  else {
    active = OFF;
  }

  return active;

}
```

To keep in line with the Javelin's CPU.readPin() method, readDigIn() will return a value of true when the signal on the input terminal is "high" (hot), and false when there is no signal present. Notice, too, that this method requires a parameter to be passed: the input terminal to check. The code will check this value and if it's out-of-range, the method will return false. Assuming a good terminal value, a bit mask is created and compared against the current state of the inputs. There is no PBASIC version of this method since the BASIC Stamp doesn't pass parameters or return values. How do we do it then? We simply call the Read_DigIns subroutine and look at the aliased bit variable of our choosing.

```
GOSUB Read_DigIns
IF (din7 = IsOn) THEN Go_Do_Something
```

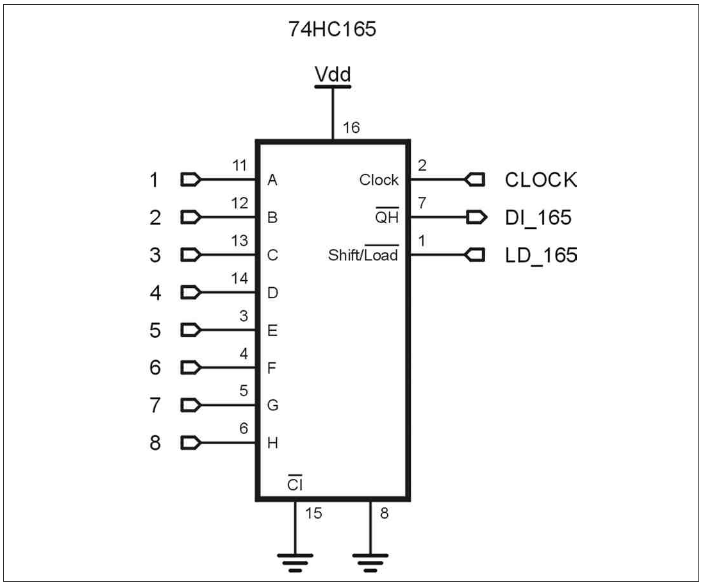
Alright, we're halfway through the digital section — more than halfway, actually, since the Stamp PLC digital outputs are direct connections and very easy to deal with. Again, let me clarify: when I say direct, I mean that we have a one-to-one control ratio with the output pins; that way when we change an output pin on the Stamp, it will directly affect the output. Of course, the Stamp module is protected from the cold cruel world of the industrial environment. The first line of protection is an optical isolation stage similar to Figure 2, then the outputs themselves are driven through high-side drivers.

A high-side driver is designed to control the "hot" side of a circuit with the other side connecting to ground (digital output ground). Since a short circuit could create a real problem for the output stage, the high-side drivers monitor output current and (device) temperature, and will shut down an output in the event of a problem.

The code for controlling outputs is as simple as you'd expect. To keep the software simple, output variables use a "1" for on, and "0" for off. This being the case, all we have to do is invert the data and write it to the Stamp port — OUTH (aliased as DOuts) for the BASIC Stamp, PORTB for the Javelin Stamp.

```
Update_DigOuts:
  DOuts = ~digOuts
  RETURN
```

Figure 3. 74HC165 Connections.



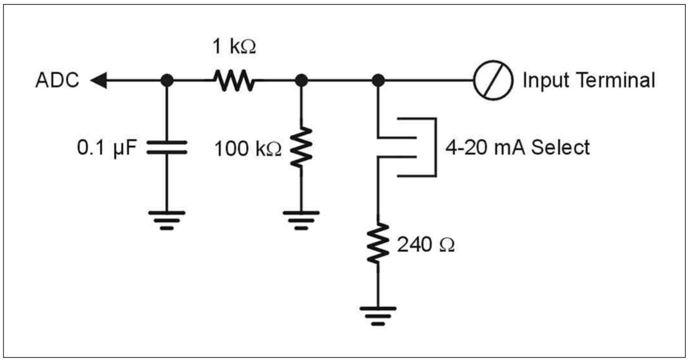


Figure 4. Stamp PLC Analog Input Protection Circuit.

And here's how we do the same thing in the Javelin:

```
static void writeDigOutputs(int newOuts) {

  CPU.writePort(CPU.PORTB, (byte)(newOuts ^ 0xFF));

}
```

The reason that the writeDigOutputs() accepts an integer value is that this will allow the programmer to pass integers or bytes — this makes things easier as the default variable type in the Javelin is the int. In the CPU.writePort() parameters, we end up type-casting the out value to a byte as this is a requirement for the method.

In the Javelin, we invert the bits by using the exclusive-Or operator. Done deal.

In order to take advantage of the Java's parameter passing, let's also create a method for controlling a single output:

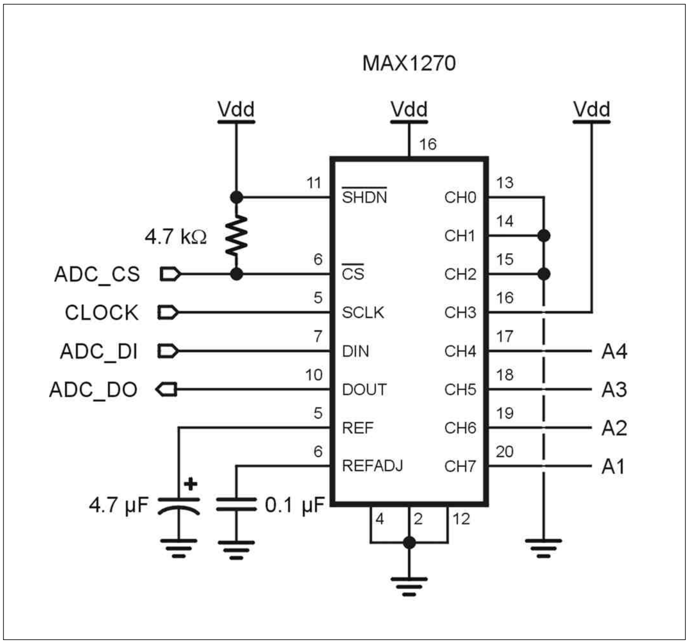


Figure 5. MAX1270 Connections.

```
static boolean writeDigOut(int digOut, boolean newState)
{

   boolean status;

   if (digOut <= DOUT8) {
     CPU.writePin(DOUTS[digOut], !newState);
     status = true;
   }
   else {
     status = false;
   }

   return status;

 }
```

This method, while simple, is a bit interesting in that it demonstrates how using a return value can be helpful, even though we're executing a command and not looking for a value. The writeDigOut() method returns a Boolean (true or false) to let us know if the output value we passed was valid. To some this will seem like overkill, but when we're creating programs that others will use, it's always a good idea to provide helpful ideas like this to protect our friends from themselves!

When a proper value is passed (0-7, aliased as DOUT1-DOUT8), the code will look up the pin value from the DOUTS array and use CPU.writePin() to update the pin. Since the state value is Boolean, the ! (not) operator is used to invert it.

We can't pass parameters in the BASIC Stamp, but what we can do is alias PIN definitions and create useful constants. So here's how we can affect an output when using the BASIC Stamp:

```
Do1 = DirectOn
```

Analog, if You Please

While there are a whole host of industrial applications that are happy to deal with nothing but digital inputs and outputs, the real world often dictates getting involved in analog values. No worries, as I told you earlier, we can install a MAX1270 12-bit ADC. The MAX1270 actually has eight channels, but only four are available for us due to the connections involved.

The nice thing about the MAX1270 is that it is software configurable; we can measure 0 to +5 volts, -5 to +5 volts, 0 to +10 volts, or -10 to +10 volts. Pretty cool, huh? The other option that we have with the Stamp PLC is that we can measure 4-20 mA signals. The way this is done is installing a jumper that routes the incoming current through a precision resistor. From the resistor, we can read the voltage and determine the level of our signal.

Before we get into reading the channels, let's talk about protecting the analog inputs — a big requirement for getting CE certification on the Stamp PLC. Figure 4 shows the circuitry between an analog connection and

the ADC. After the shunt you'll see a 100K, a 1K and a small cap. The 100K helps reduce noise susceptibility of the high-impedance ADC inputs by reducing the input impedance a bit. The 1K limits current to the input and the cap will bypass high-frequency noise. Figure 4 shows the analog input protection circuit.

The reason for discussing this is that these components will have a small effect on the input signal. I found that when I applied 5.00 volts to an input pin, I was reading about 4.75 volts at the ADC. This is no big problem; after we read an ADC channel, we'll apply an adjustment factor to scale the input to the "external" signal level.

Figure 5 shows the Stamp PLC connections to the MAX1270 ADC. As you can see, we're only using four of the eight analog channels; the others are tied to ground or Vdd (this is useful for device verification). The MAX1270, like the 74HC165, is a synchronous serial device. A key difference is that the MAX1270 uses a chip select line so that its data lines can be shared with other devices. The 74HC165 has no chip select, so the only common line between the two is the clock.

Accessing analog data is pretty easy: We select the MAX1270 by taking the CS\ line low, use **SHIFTOUT** to send the configuration byte, then release the device. It takes less than a millisecond for the conversion to take place, but we do need to insert a very short delay to make sure this happens. After that, we reselect the device and use **SHIFTIN** to retrieve the 12-bit value.

The configuration byte tells the MAX1270 what range to use and what channel to read. To make things easier, possible configuration bytes are predefined as **DATA** values in the BS2, and in a constant array in the Javelin. Both versions of the program allow us to set the mode (voltage range) and channel so that the configuration byte can be retrieved.

Let's look at the BASIC Stamp code for reading a channel:

```
Read_ADC:
  READ AdcCfg + (mode * 4 + chan), config
  LOW AdcCS
  SHIFTOUT AdcDo, Clock, MSBFIRST, [config]
  HIGH AdcCS
  adcRaw = 0
  LOW AdcCS
  SHIFTIN AdcDi, Clock, MSBPRE, [adcRaw\12]
  HIGH AdcCS

  adcRaw = adcRaw + (adcRaw ** $D6C) MAX 4095    ' x ~1.05243
```

The program uses two variables — mode and chan — to calculate the table pointer for the configuration byte. The rest of the code should make perfect sense. Remember that **SHIFTIN** and **SHIFTOUT** default to eight bits, so we have to use the \12 modifier with **SHIFTIN** to retrieve all the bits from the MAX1270.

The final line of code above is the adjustment for the input protection circuit. As you can see by the comment, we're multiplying the raw ADC value by 1.05243. In order to get the best resolution, I used my buddy Tracy Allen's trick with the ** (star-star) operator. Star-star, as you'll recall, allows us to multiply values in increments of 1/65536.

Okay, now let's look at the same code in the Javelin:

```
static int readAnalog(int channel, int mode) {

  int config;
  int adcRaw = 0;

  config = ADC_CFG[mode * 4 + channel];
  CPU.writePin(ADC_CS, false);
  CPU.shiftOut(ADC_DO, CLOCK, 8, CPU.SHIFT_MSB, (config << 8));
  CPU.writePin(ADC_CS, true);
  CPU.delay(1);
  CPU.writePin(ADC_CS, false);
  adcRaw = CPU.shiftIn(ADC_DI, CLOCK, 12, CPU.PRE_CLOCK_MSB);
  CPU.writePin(ADC_CS, true);

  // adjust counts for input divider (protection) circuity
  // -- cal factor = (input on terminal) / (input to MAX1270)
  // -- 1.05243

  adcRaw = adcRaw + (adcRaw / 20) + (adcRaw / 412);

  return adcRaw;

}
```

The bulk of the code is not dramatically different, except that we can pass the mode and channel values as parameters.

One thing you'll notice is that the config byte is shifted left by eight in the CPU.shiftOut() method. The reason for this is that the Javelin uses integers internally and since we're shifting the MSB first, we have to move the byte MSB (bit 7) to an int MSB (bit 15).

Now, there is no equivalent to the ** operator in the Javelin, and I wanted to keep the program simple and not involve any classes beyond CPU. (Note: There is a simple floating point math class available for the Javelin.) What this means, then, is that I had to do a little math to create the adjustment line. This was actually very easy. What I did is split the fractional portion into two parts: 0.05 and 0.00243. Then I entered 0.05 into my calculator and pressed the reciprocal (1/x) key — that gave me 20. Then I did the same thing with 0.00243 and got 412.

We are Ready for Timely Control

Up to this point, we've created I/O control routines for a generic controller. What do we do now? Well, anything we need or want to do. What I'd like to show you, though, is why the Javelin can be such a great little controller in industrial applications.

The Javelin has a timer object that runs in the background and can actually control as many timers as we might need in our program. Once we've defined a timer, it simply increments its counts until we reset it with the mark() method. The simplest way to use a Javelin timer is to check its count with the timeOut() method. Let's look at a simplified Javelin shell for a time-specific control application.

```
public static void main() {

  Timer scanTimer = new Timer();
  scanTimer.mark();

  while (true) {

    if (scanTimer.timeout(100)) {
      scanTimer.mark();

      // control logic here

    }
  }
}
```

In this shell, a timer is created and immediately reset. With the while loop (which will run forever), the timer is checked to see if it has reached 100 milliseconds. When that condition is true, the timer will be reset and the code that is intended to run every 100 milliseconds will execute.

This is a very simple, yet incredibly powerful feature of the Javelin. And it's tough to duplicate on the BASIC Stamp with **PAUSE**, since any change in our operation code means we have to adjust the **PAUSE** duration.

The full listings include more demo code to study and use, so be sure to download them from the *Nuts & Volts* website at **www.nutsvolts.com**

Whew ...

Okay, I know that for some of you, your heads are spinning — imagine how I feel having spent three solid days of my life writing this! I recently said to a friend that it is much easier to write a program than to write *about* a program.

I hope, though, that you found this article valuable, especially if you've been a bit shy about trying the Javelin. It has taken a little time to catch on, probably because Java is a more disciplined language than PBASIC, and takes some getting used to.

That said, we're seeing more and more BASIC Stamp users give the Javelin a try and do some really neat things.

The good news is that Java is growing as a language and is being taught in more and more schools. And remember that you can always run down to your favorite bookstore and find shelves full of books on programming in Java.

While it's true that a lot of the programs in those books won't run on the Javelin (there is no GUI in an embedded micro and other desktop computer stuff is irrelevant), the concepts and programming strategies are all valid.

My favorite book on Java is called *Head First Java* by Kathy Sierra and Bert Bates (ISBN 0596004656). It's the first technical book I ever purchased that is actually fun to work with.

Let me finish by saying that in my Javelin Stamp PLC program, I actually kind-of violated the Java "norm" by not breaking my program into multiple classes. The reason is that I wanted to create a project that was easy to use for programmers without much Java experience. As my own Java expertise grows, I *am* doing that, and you can download a modular (with reusable classes for the 74HC165 and MAX1270) version of the Stamp PLC from the Parallax website (**www.parallax.com**).

Okay, I've had enough; have you? I thought so. Until next time then, Happy Stamping. **NV**

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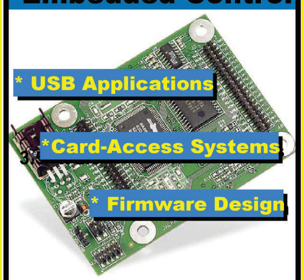

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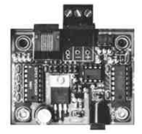

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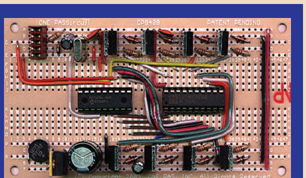

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In The Trenches

Intellectual Property Protection

So, you've just conceived the best idea ever. How do you protect it? There are four basic protection tools available that need to be defined before any discussion can proceed: patents, copyrights, trademarks, and secrets. After the definitions, the pros and cons will be discussed.

Patents

A patent is a formal government conferred right for the commercial production of some product or process by the US Patent and Trademark Office (PTO). There are three areas of patent protection. The first is a "utility" patent. This is generally the "better mousetrap" group of products. However, this also includes procedures. For example, if you have developed a new way of doing something, rather than the something itself, you can get a patent.

Then there are "design" patents. These are for the appearance of a product, rather than for its performance. You can patent the front panel layout, for example, so that no one can make a product that looks like yours.

Lastly, there is the bio-medical "plant" patents. These are for gene-modification and the byproducts from them. You probably aren't likely to be involved in this, if you're reading this magazine.

Patents provide a legal basis for a lawsuit and can be enforced for up to 14 years. The original idea of the patent was to provide protection for the start-up of a business until the business could become established. US patents are not good overseas. Additional patent applications must be made for foreign countries (with a few exceptions). World-wide patent protection is extremely expensive. (If you have to ask "How much?" you can't afford it.) A much more detailed presentation on patents was published by Danny Graves in the September 2003 issue of *Nuts & Volts*.

There is also the "Provisional Patent Filing." This is a relatively inexpensive method (about $1,000.00) that basically provides a preliminary date for filing. There are no patent claims and no patent examination. The PTO simply files the invention and assigns a date. You have a year to apply for a formal patent.

Usually this is used to determine the value/market of an invention before filing for a standard patent. The important point is that the invention has a date assigned to it. This helps settle disputes about who filed first for similar inventions.

My Patent Story

In April 1996, I went to a patent attorney and started the patent procedure. I did most of the work. I wrote the body of the patent and drew the illustrations. The attorney wrote the claims and an associate re-drew the illustrations to the proper specifications. It was filed with the PTO on August 2, 1996.

After the patent review and additional clarifications, the patent was granted on September 29, 1998 (Patent 5,815,101). The elapsed time was about 2.5 years. My costs were $9,195.00. And that doesn't include continuing patent maintenance fees.

I recently called several patent law firms to determine what the current costs were. I was told that typical utility patent costs are in the $15,000.00 to $20,000.00 range. Remember, this is for the legal fees associated with developing the patent.

There are some firms that will simply file the patent for you. One firm I talked to would do this for $1000.00. But that's all they do. They don't look at the patent itself.

You can do everything yourself. However, this is risky. The actual patent protection comes from the claims at the end of the patent. If these are not written properly, the patent may not cover very much.

Look at some patent claims. You'll see that they have a writing style that is not transparent. It's difficult to follow what the claims mean. It's much harder to write the claims. At the very least, a patent professional should review your application, not just file it.

Copyrights

Anything written on paper can be copyrighted by simply saying so. The copyright symbol — a "C" with a circle around it — can also be used. The date should be included, but is not necessary. A copyright provides legal rights against the direct copying of text or pictures.

The electronic "paper" of the Internet is somewhat vague in some details about copyrights. But, generally, if someone copies what you have written, without your permission, you have a basis for a lawsuit.

Obviously, you cannot copyright

the alphabet or individual words. Common sense applies here. If someone copies a chapter of your book, you have a good case. If someone uses the same sentence, your case isn't as good.

Copyrights were developed to protect writers from outright theft of their work. It basically says that you cannot COPY someone else's work. Note, it does NOT protect the information contained in the words.

Trade Names and Trademarks

A trademark is a unique indicator of a business. The US PTO confers trademark status for the US. It is generally quite inexpensive to register a trademark, usually less than $1,000.00. Of course, if you want to register green double arches for your fast-food restaurant, you may face an argument.

Trademark protection was developed to prevent customer confusion. For example, I couldn't trademark green double arches for my fast-food restaurant named McDougle's. However, if my name was McDougle and I was in the bridge building business, then I probably could trademark green double arches. Obviously, a customer knows the difference between a hamburger and a bridge.

A classic example of this is Apple Records and Apple Computer. Everyone knows the difference between a recording and a computer, right? Except that Apple Computer is now allowing music downloads. The line between the companies is getting fuzzy. It is my understanding that legal negotiations are underway.

Secrecy

Sometimes, simply keeping secrets is good protection. If you have a method of manufacturing that costs less, simply don't tell anyone. Trade secret law might protect you, although you have no guarantee. If someone uses illegal methods to obtain your secret, you can sue.

Protection Fallacies

Here are several urban legends that are associated with patents and invention protection.

Fallacy 1: *I'll write a letter to myself that contains my invention. When it arrives, I won't open it, so I'll have proof of when I thought of it. This will give me patent protection.*

This is absolutely useless. A patent is given according to the filing date. It you don't file, you have no protection.

Fallacy 2: *I'll copyright my software. That way, I'll protect the special method I've developed for obtaining square-roots.*

Wrong! All you are protecting is the actual code, not the idea. Someone else can take the procedure and simply use a different language.

Even the same language can be used, if the code is changed enough so that it looks different. (Didn't you do the same thing in school?) If the code is not actually copied, there is no protection.

Fallacy 3: *The advertisement says that the product is patented, so it must work.*

Patents only show originality, not efficacy. I can get a patent for attaching magnets to house flies so that when they land on a steel garbage can, they can't fly away. The patent examiner doesn't care if the invention works or not; or if it's practical or not. Only if it's new. A patent in no way suggests that a product works as advertised!

Fallacy 4: *I want to manufacture my product, so I need a patent.*

A patent only provides a legal basis for a lawsuit if someone copies your invention. It is not needed for manufacturing or business.

Fallacy 5: *If I don't patent my invention, then someone else could do so and prevent me from manufacturing it.*

If you are already selling your invention before your competitor files, there should be no problem. You may have to prove this in court. In fact, in this case, if you inform the PTO of this, the patent might be with-

drawn. However, since you have no patent, you can't stop your competitor from manufacturing the product, too.

If the competitor files before you start selling your product, then you have a problem. This is the basic reason for obtaining a patent in the first place — to give the patent-holder an advantage.

Patent and Marketing Scams

Beware of any company that says it will "develop and market" your idea. If you are lucky, they will include your idea in a book of hundreds or thousands of other unrelated ideas and send them off to a handful of uninterested companies. It's human nature to want to see your idea succeed. These people use that for their profit. Only work with reputable agencies.

There are others who will get a "design" patent instead of a "utility" patent. It's much cheaper for them. But, of course, a design patent only covers what the product looks like, not what it does. So, it's not very useful for you. Understand what you are getting before you pay your money.

Protection Guidelines

Obviously, there is no way to discuss all possible methods of protection for all cases. However, it is possible to sketch out some basic guidelines.

There are two basic considerations that have to be made before thinking about a patent. The first is financial. If you spend $10,000.00 on a patent, how many units must you sell to recover that investment? Suppose your product's selling price is $500.00 and the basic profit is $200.00 per unit. You have to sell 50 units to recover that cost. On the other hand, If your product sells for $50.00 and the basic profit is $20.00, you have to sell 500 units. (And, if your basic profit isn't at least this big, you'll have problems making money.)

So, the question here is can you afford it? Would that $10,000.00 be better spent on advertising or better manufacturing equipment? It is surprising how often this fundamental consideration is ignored.

The second point is what I call the "Wow" factor. If a customer looks at your product and thinks "Wow. How can they sell this so cheaply?" then there is little chance of someone copying your product. Conversely, if they think "Gee, I could make this for 1/10 the cost!" then there is incentive for copying. More simply put, a good product at a good price is often all the protection you need. This is also called good business. The object of copiers is to make money. If someone can't make a lot of money duplicating your product, they won't.

Generally, I suggest to my clients that patenting a product is not cost effective. The money can usually be better spent in other areas. If a patent dispute should arise, it will cost a lot of money to resolve. Can you afford to front $100,000.00 in legal fees? How many sales will be needed to recoup these expenses if you lose? (If you win, often the other side pays for the legal costs.)

Probably the most difficult thing to do is place a realistic "worth" estimate on an invention. The inventor always thinks it's worth much more than it is. That's just human nature. However, calculating the worth through a realistic sales volume provides a more objective guideline. Of course, over-estimating sales volume is also common. Be conservative.

I tell my clients that a patent should be considered for a process (not product), if that process has widespread utility. For example, if you've figured out a process for sending data at 1 mega-bits/sec. over ordinary telephone lines, seriously consider a patent. (My patent for post-sampling anti-aliasing has not made any money for me.)

Less Direct Protection Methods — Secrecy

There are things you can do to make your product less likely to be copied. Remember, copiers are looking for an easy buck. Making it difficult for them aids your protection. That said, there is still no guarantee that someone won't copy it.

For embedded software, the best protection is the code-protect option of the microcontroller. This prevents anyone from reading out or copying the code. If you aren't using such a controller, you should. Putting the code into an ordinary EPROM is just like publishing it.

If you have to have an external ROM or RAM, then encode the data. This doesn't have to be a sophisticated cipher. There are lots of simple procedures that can be frustrating to would-be thieves. For example, change the LSB/MSB order in every other location. Add spurious and meaningless data. Change the data values by their address. Be creative! It won't take you much time to recode your data, since you know what you are doing. But, to an outsider, it will be a mess. (Be sure to document what you do so that authorized technicians can properly troubleshoot the unit.)

Always add "copyright" to all code. It may not be worth too much but it's easy to do and can give some protection. Even if it's only psychological.

Also, copyright all printed circuit boards. This is important and useful. It means that a potential thief has to re-layout the board. This means more work and potential problems.

Copyrighting schematic diagrams and other drawings is also useful. Technically, if they copy your product and try to produce it, they are sometimes forced to copy the documentation. This may give you a legal basis for a lawsuit.

If you can substitute a microcontroller for your hardware, do so. The internal code-protect is very good. Of course, there is a trade-off here. If the controller costs more than the hardware, is the added protection worthwhile? However, with controllers being so cheap now, this consideration is becoming moot. If the hardware is extensive, consider an ASIC instead of a controller. They have code-protect, as well.

Use signal decoys. Have the controller send and receive meaningless signals. If these signals change, shut down the system. This makes it look to an outsider that these signals are important. Be careful not to affect the reliability of your product.

Hardware can also be used as a decoy. This approach is clearly expensive. It only makes sense to use this technique if there is a large profit margin. Simply put, add additional hardware and a controller to monitor the hardware. The additional hardware actually does nothing meaningful. However, the controller sends signals to it and receives signals from it. If the controller detects changes to the circuit, it shuts down. In this way, anyone playing with the phony circuit crashes the system. Adding confusion helps to prevent copying and protects your product.

As you can see, there are a lot of secret ways to protect your product that don't cost very much. Your imagination is your best asset here. Remember, a product will only be copied if it is financially advantageous. If the copier has to spend weeks or months trying to figure out your product, he'll look elsewhere. Copiers don't want to work. If they did, they'd design their own products!

Non-disclosure Agreements

Often you want to share your information with another company. This may be because you want them to provide financial support or you want them to produce your product. In this case, you want a "Non-

Disclosure Agreement."

Basically, this is a contract between two parties (you and someone else) to keep a secret. You offer to give them information so that they can evaluate or produce it and they agree it's your property. There are a lot of different types of non-disclosure agreements. I've seen some run to three pages.

Reputable companies will always be willing to sign a non-disclosure in some form. Some companies have their own version that they insist on using. Beware of anyone who balks at signing an agreement. Always carefully read anything you sign. Some unscrupulous companies may try to take advantage of you. But, this is rare.

This agreement protects the companies, as well. If they are working on a similar invention, or if the invention has already been in the public domain, they are protected. Some disclosures have a time limit. Generally, this is five years. You can search the web for typical non-disclosure statements.

If you are concerned about the terms, have your lawyer examine the statement. Unfortunately, access to a lawyer is becoming just as important to business as business cards.

Conflict

After all this, suppose someone copies your work. What do you do? *Any and all* protection methods only provide you for a *basis* for a lawsuit. That means legal action. That also means spending a lot of money. Legal action also takes a long time, often years. Can you afford it? Can you afford not to? This is a hard decision to make. Of course, you feel angry, but don't let anger get in the way of a good decision. Sometimes the simple approach works. Have your lawyer write the copier and threaten a lawsuit. Also contact distributors and tell them about the copying. Provide absolute proof. If you can't prove it, you will have trouble winning a lawsuit. Also remember that need drives product development. Often, the same idea happens at about the same time because of a common need. Be objective. It's usually obvious if someone independently developed a product or just copied it. Product competition is the American way. Using inappropriate methods to quash competition can get you into trouble.

The same is true if the reverse happens — if someone tells you that you are infringing on their rights. React calmly. Talk to your lawyer. Look at the financial implications. Look at the proof. Make a decision based on good business. Otherwise, you may just be wasting a lot of money.

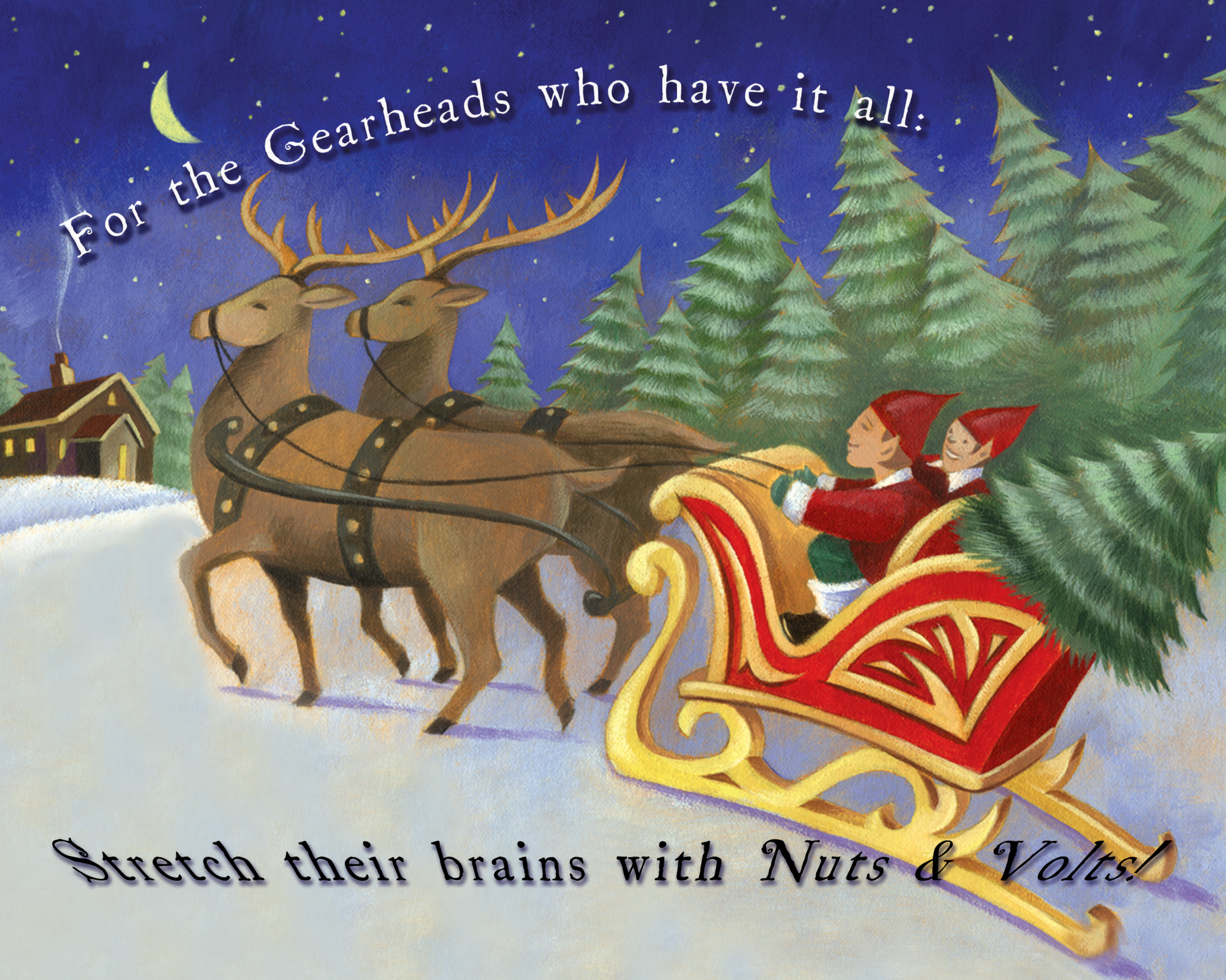
Forrest Mims III vs. Bell Laboratories

Way back in the 1970s Forrest Mims III documented a way of using an LED to respond to light. He thought it would be a good way to allow two-way communication over fiber-optic lines. He submitted the idea to Bell Labs after signing a non-disclosure agreement. Bell rejected the idea. However, a few years later, Bell released a "new" device that could both emit and detect light. Mr. Mims was upset and eventually took Bell Labs to Federal Court. More details are available in the April and May 1982 issues of *Popular Electronics*. Mr. Mims spent hundreds of hours researching his case and writing briefs for his attorneys. He had to allow his office/home to be searched. Some of his friends and colleagues were subpoenaed by Bell. It was not a pleasant experience. Nevertheless, he was able to settle out of court and with a check from Bell Labs. Sometimes the little guy actually wins! But, Bell never admitted to violating the non-disclosure agreement.

Conclusion

There are a lot of methods you can use to protect your idea. No method is best and the procedure you choose depends on your situation and product.

Any protection is a trade-off. You have to spend time, money, or both. Naturally, it's important to apply the correct method, otherwise you're just wasting time, money, or both. **NV**


For the Gearheads who have it all:
Stretch their brains with Nuts & Volts!

Your Personal Robot Minion

The *Nuts & Volts* editorial staff recently had the opportunity to visit COMDEX in Las Vegas, NV, where we found robot creator Mark Tilden set up on an unassuming card table in the middle of an aisle. Looking dangerously casual in the midst of the palpable tension of a dramatically scaled down show, Tilden was demonstrating a small army of robot toys, his soon-for-sale RoboSapien product. Powered by conventional D cell batteries and commanded by a remote control with more buttons than a Michael Jackson outfit, the fleet of 'Sapiens walked, swung their arms, and grunted in unison. Very impressive for a toy that Wow Wee, Ltd., plans to sell for $100.00.

Tilden — infamous for getting his earlier Furby toy banned from the Pentagon over security issues — is unrepentant in his outright dismissal of the Japanese offering of current high tech robot toys — his does everything theirs does, and is cheaper. Claiming to have built the prototype in only nine months, he also has plans for a follow-on "female" version that, reportedly, will be able to order the existing male 'Sapiens around by voice command. I wonder if the arms are jointed properly to place their hands over their ears? (You can view a video clip we shot of the RoboSapiens in action from our website, **www.nutsvolts.com**)

When Water and Electricity DO Mix

A team led by Professor Daniel Kwok and Professor Larry Kostiuk from the University of Alberta, Edmonton, Canada, has developed the first new way to generate electricity since 1839. Kwok, Kostiuk, and their collaborators describe a method of generating electrical power from the natural electrokinetic properties of fluids forced through microchannels.

The electricity is generated by separating electrical charges in the fluid at a solid-fluid interface. When the solid is in contact with the fluid, some of the atoms in the solid disassociate — forming negative, free electrons and positive ions. Depending on the type of solid, one or the other of these will flow off into the fluid, leaving the solid with a net charge. This separation of charges on either side of the channel creates a voltage between the two ends. If an object, like a cell phone, is connected between the two ends, a current will flow that can be used to power the device. Although the power generated from a single channel is extremely small, millions of parallel channels can be used in a small volume to increase the power output to useful levels.

Tech Forum

QUESTIONS

Does anyone have software for the old PC82 device programmer? The manufacturers, Citadel Products, LTD., England, does not respond to Email.

#1041 **Cassie Carstens**
South Africa

I've been studying electronics on my own but am still a novice. I would like to light a crystal from underneath with lights that slowly illuminate and fade to produce different colors. I have made a couple different circuits using blue, red, and green LEDs and triangle wave circuits but they are not as bright as I'd like.

I've seen a circuit using Christmas tree lights but it requires programming a chip which I don't know how to do. I've seen these in stores and I suppose I could buy one and take it apart, but I expect they also have programmed chips.

If I could figure out how to use a nine volt triangle wave generator to control a 110 VAC circuit I might have what I want. Any suggestions out there?

#1042 **Glenn Erickson**
via Internet

How can I burn old and obsolete tapes and records onto CDs? I have a CD-R/W drive and have copied CDs, but I can't figure out how to input from an outside-the-computer source.

#1043 **Anonymous**
via Internet

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

Send all material to *Nuts & Volts Magazine*, 430 Princeland Court, Corona, CA 92879, OR fax to (909) 371-3052, OR email to forum@nutsvolts.com

ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
- Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO
To be considered

All questions should relate to one or more of the following:

1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions

- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions may be subject to editing.

Helpful Hints

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

I'd like a circuit that can capture theater or TV scene breaks based on sudden variations in screen light. I tried this with an LDR and a few transistors driving a small relay linked to a counter, but the response was not fast. Using a phototransistor, I got vertical sync pulses instead of scene breaks. I did find some capture ideas based on digital principles and the analysis of MPEG images. Does anyone have any ideas about how to do this?

#1044 **A. L. Sairam**
Brazil

I'd like to build a simple interval timer to run a 12 volt CPU cooling fan. It should turn the fan on for five minutes and then off for about three. If it was adjustable, that would be even better. Does anyone have a schematic for such a device?

#1045 **Bob Eshoo**
Santa Monica, CA

I was in a shop and observed a desk clerk verify that the stone in a diamond ring was genuine. He used a probe device that became warm at the tip, it was placed against the stone in question, and a red or green LED illuminated to indicate authenticity. I know diamonds conduct electricity *(actually, they don't — Editor Dan)* but how does this thermal testing device work?

#1046 **Gordon McKittrick**
Haure, MT

I've seen ads for 100 — 150 foot USB boosters that use standard CAT-5 cabling. How would one go about building one of these? It seems to me all it would need to be is a couple of high speed amps, one near the PC, and one more on the other end of the cable, with power being supplied through one of the other pairs in the cable.

#1047 **Ross**
via Internet

I have a Super-8 motion picture camera that runs on a 7.2 volt battery. The problem I'm having is that it doesn't run in sync with the sound. I recorded the sound on a digital real-time recorder, but the

camera dosen't have real time sync.

I'm going crazy looking for kits or plans to build my own crystal sync as I can't afford to pay $800.00 for a commercial unit. Can anyone please help me find a kit or plans on building my own crystal sync for a 7.2 volt motor? I tried searching the Internet but there is no information available! Thank you!

#1048 **Alfredo Parra**
via Internet

I salvaged some lithium-ion rechargeable batteries to use in a project and now I need to build a charger for them. They are 3.6V, 1200 mAh in size. I have a NiMH battery charger already, can I use that?

#1049 **Raymond Capton**
Troy, MI

I am looking for a simple circuit that will electronically report the amount of angular rotation about an axis, to 0.1 degrees resolution. Does anyone have a reference to the parts to construct such a sensor?

#10410 **Bill Hepner**
via Internet

I am looking for circuit that would measure femtofarad amounts of capacitance. I am also trying to build tunnel diode oscillator that would oscillate at 1 GHz. Does anyone know where to buy tunnel diodes? Thank you for your help.

#10411 **George Zrilic**
via Internet

I want to create a digital thermometer with a four Nixie tube display. I am really having difficulty finding anything even remotely close to this. Can anyone point me in the right direction? I'm mainly looking for a circuit design ... hopefully, I can figure out the rest.

#10412 **Mike Galloway**
via Internet

My cordless phone does not talk loudly enough as a phone but does very well on intercom. Panasonic does not care to answer why. Could someone throw together a circuit that might amplify the output that drives the receiver, both ends of which are above ground? I suspect one lead is the driver and the other is a muting control. (I do not want to use a strap-on amplifier.)

#10413 **K. A. Caldwell**
via Internet

I have an old TRS-80, and some idiot overwrote the master disk when I loaned it out! I am looking for a replacement that works, and will pay for a download, disk, or any fix.

#10414 **Robert Gibson**
via Internet

I have a Compaq Presario 1277 laptop, with a Li-Ion battery bearing the notation "14.8V, 3.2AHr." I'd like to know what this actually means, and if possible, how to calculate the battery's actual output, the amount of time it will supply needed power, etc.

I also wonder if it's at all possible to replace this battery with a home made solution, from something I read several issues back about super capacitors (1 Farad and greater).

#10415 **Phillip Lessley**
via Internet

ANSWERS

[10038 - October 2003]

I have taken the output from my PC sound card and run it into the phono input on the back of my stereo. I have this loud hum coming from my speakers along with the audio from my PC.

You are hearing hum from your sound card for two reasons. First, you are using the "phono" input of your stereo, which is highly equalized for playback of records (big black round things with grooves). In addition to being a high gain input for dealing with the tiny signals found on phono cartridges, it emphasizes the bass much more than you need, and will therefore amplify any hum on your soundcard a lot. The result is way too much gain, and even more in the bass "hum" range. You should be using a "tape," "tuner," or "aux" input, which is unequalized, and of the proper gain.

The second reason you get so much hum is many computers can create a "ground loop" when connected to ungrounded stereos. You might try just running a ground wire from your stereo to a good electrical ground (but don't go sticking it in a wall outlet!). Or, easier but more expensive, go to RadioShack and pick up a 270-054 Ground Loop Isolator. This product is actually for the car stereo market, but for about $15.00, it solves most audio ground loop problems found around computers, too. Just use it between your sound card and stereo. It's a pair of audio transformers encased in a 'blob.' I keep one around for solving just this sort of problem.

Jim Addie
La Grange Park, IL

[11032 - November 2003]

I need a circuit that can measure viscosity of oil at temperatures up to 250 degrees F and under pressures of up to 200 PSI. I was thinking that a quartz crystal, with a self resonating circuit, could just measure the different frequencies, as I know temperature would affect the results. Would this work? I could submerse a motorized paddle in the oil and measure the motor current, but it would be hard to build because of the pressure, temperature, and sealing.

The device you are asking about is known as a viscometer. Googling "viscometer" produced over 38,000 web pages, the overwhelming majority of which are from manufacturers or distributors of commercial viscometers.

Your idea of using a motor-driven paddle is not bad, although many rotational viscometers use a cylinder rotating within a slightly larger cylinder to achieve the same effect. The problem lies in the fact that you must then know how to convert the rotational force measurement (motor's current variations or motor voltage required to produce a specific shaft torque) into standard viscosity readings, typically measured in kinematic centistokes or pascals. Surprisingly, a physics student at Imperial College, University of

London has a paper on the web that details the theory and process of designing and building a microprocessor-controlled viscometer. Go to **www.hanssummers.com/electronics/viscometer/visc.htm** for the illustrated paper. Copying such a device exactly would theoretically save you having to buy a commercial viscometer in order to calibrate a home-built viscometer. Good luck on your project, and I hope this helps.

Gary Sandino
via Internet

[10039 - October 2003]

*My Kenwood TS440S is beginning to present symptoms (frequency drift and intermittent dots in the display) of PLL unlock. Service bulletins at **Kenwood.net** suggest that replacing a fist full of diodes with new diodes of any of these types — 1S2588,1SS91S, and BA282 — will cure the problem.*

Additionally, I have heard that 1S1587 diodes can be used. However, I have been unable to find a source for these parts that will send or sell me just a few.

#1 Go to the Kenwood website, enter the service bulletin section and locate bulletins ASB0973 (TS-440S PLL UNLOCK DUE TO VCO, dated 08/08/90) and ASB0974 (TS-440S PLL UNLOCK DUE TO PLL#1, dated 08/08/90).

The most likely cause is found in bulletin 0973. Kenwood advised that the rubberized potting compound ages and causes the components to become "heat sensitive." The unit will cool off, and then the VCO will unlock, causing all dots to appear on the display. When the dial is rotated, the display will return but as soon as the dial stops being moved, the display will return to all dots. After the 440S heats up, the VCO will "drift into lock" and the rig will work.

Kenwood bulletins note that the "cure" is to remove the potting compound, replace some parts, replace the potting compound, and retune the VCO. ASB0973 talks to two transistors and one varactor diode. Note that if you do the repair yourself, take your time, be careful, and watch how you are monkeying around in the small compartment that the VCO is contained within. It is a 'doable' job ... but you must take your time and be patient! If in doubt, let a professional do it. It may cost more, but peace of mind is less expensive than a repair bill for the problem and the added costs for repairing your zorched up work, as well!

Before replacing parts, try the following (which worked on my 440SAT.) The VCO is located inside a small, silver-colored metal box with a cover atop it. This cover can be gently pried up and removed. It is a press-fit friction fit cover. Inside, you will see whitish potting compound, a small IF-style transformer with the top-accessible adjustable slug, and other

components. This is the VCO.

There is a small IF-can sized coil labeled in the service manual (available from **www.w7fg.com**) on page 72, "PLL UNIT VIEW," identified as T20. Due to vibration, the slug of T20 can move, and this will cause the VCO to go into an unlock mode or shift the tuning of the VCO to the hairy edge of being locked.

Dial in a known frequency (I use WWV) and measure the VCO voltage as per Kenwood's recommendation, and gently (using a proper tuning tool) rotate the slug and watch the 440S display. At some point, the display will change from dots to the frequency you selected. You should hear the receiver come back to life. You may have to tune the coil to get the station you tuned in to be heard.

This is only a way of proving that you can adjust the VCO back into range to lock. You will probably have to replace the parts as shown in the ASB0973 bulletin. Retune the VCO as per the service bulletin.

Chuck Reville K3FT
Baltimore, MD

#2 BA282 diodes are stocked by Surplus Sales of Nebraska. Their telephone number is 402-346-4750.

Anthony Caristi
Waldwick, NJ

#3 Two of the diodes you listed — the BA282 and the 1S1587 — are listed in the catalog of RF Parts, San Marco, CA. I have not checked stock. Their toll free number is 800-737-2787. I have had limited dealings with them, but they have proven very responsive.

Mark Van Sickle KG4ORA
via Internet

#4 These parts can be ordered online from **www.pacparts.com**

The BA282 was in stock when I checked for $1.74 each. I hope the repair is successful!

Howard Krausse
Ann Arbor, MI

[100310 - October 2003]

I have a JVC handy-cam (Mini-DV Model DVL 505). It has a small battery that does not last long. The JVC AC power supply (Model AAV-40) for that camera has an extension cable that will supply DC voltage instead of the battery, if desired. The book says that the battery is 7.2 volts and that the AC power supply puts out 6.3 volts. Can I power this camera with a 12 volt gelcell without damaging it? I suspect I can because devices like this can use automobile lighter adapters that sell for about $15.00, so, I doubt there are any magic voltage regulation circuits in them.

#1 Don't plug that 12 V into your little camcorder! There's a good reason why the batteries and the AC supply hang around 6 V. If you want to run the camera off your 12 V gelcells, do it the safe way, and purchase the JVC AP-V8U car cord designed for your camera ($49.00 from **www.jvcservice.com**).

Its specs say it's a 12 V in, 6 V 1.8 A out device, so yes, it does have a regulator in it. Then, shoot by **www.partsxpress.com** and pick up a 265-235 cigarette lighter extension cord. You only are after the nice cord mounted socket, which you can cut off, leaving a few inches of wire. Crimp on a couple of 1/4" F-disconnects (095-300 from partsxpress) which should mate with your gelcells, and carefully check polarity to make sure you are feeding + to the center of the lighter socket. Plug in the car cord, and you'll feed your camcorder its favorite flavor of nicely regulated 6 VDC.

You'll probably find similar parts at RadioShack too, but stick with the JVC car cord.

Jim Addie
La Grange Park, IL

#2 Rapid LLC makes the product you need. It has been tested with JVC cameras and works great. The design of the product is based upon TI's Integrated Switching Regulator. It is a bad idea to simply put 12 volts into an expensive device that requires just 6.3 volts.

The ISR is a high efficiency voltage regulator that will provide the correct voltage to your camera. This product accepts input through a four pin DIN connect. As a professional cameraman, you will recognize that as being the video industry standard connector for DC power. Full specs can be found at: **www.digitalproduction.info/hd10uMatteBox.htm**

Jon B. Bushey
Salt Lake City, UT

[11031 - November 2003]

I am using a 4017 sequencer IC to light a small Christmas display, using the first nine steps to light each element. On the tenth step, I would like all nine outputs to light up, and then repeat. I am using relays (12 volts, 700 ohm coil) to interface the IC and display, but, I can't get the nine outputs to light all at once.

Outputs for the 10 taps of the 4017 are T0=pin 3, T1=2, T2=4, T3=7, T4=10, T5=1, T6=5, T7=6, T8=9, and T9=11. For each of your relay inputs — which should be connected to one of these T# points — you need to insert a two-input "OR" gate. If we name the relay coil wire previously connected to T0 as "R0," then "R0" connects to the output of a two-input "OR" gate whose inputs are "T0" and "T9." "R1" connects to the output of a two-input "OR" gate whose inputs are "T1" and "T9". This pattern carries through for the remainder of the relays.

Typical "OR gate" ICs such as the TI CD4071B only contain four gates, so you would need three chips to handle T1-T9. I have not tried this, but I think you could do this much cheaper by implementing your own "OR" gates with a pair of diodes:

```
T0 ——|>|—— +
           + —— R0
T9 ——|>|—— +
```

Assuming that the voltage drop across the diodes still leaves enough voltage to drive your relay coils, this should serve to isolate your inputs. A Schottky diode such as a 1N5817 is recommended to minimize the voltage drop.

Barry Cole
via Internet

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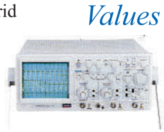

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